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University of Maine.

Maine Agricultural Experiment Station

ORONO

BULLETIN No. 179. **MAY 1910**

POULTRY NOTES.

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BULLETIN No. 179.

POULTRY NOTES—1909.

RAYMOND PEARL AND FRANK M. SURFACE.

The purpose of this bulletin is to present a brief report of the progress of the work of the Station with poultry during the year 1909. The publication of such summary reports annually is a definite policy of the Station. It is the object of these reports not only to give an account of the work done, but also to present a more or less complete account of various points regarding poultry management, which arise incidentally in connection with the main lines of investigation which are being followed with poultry. These main lines of investigation are poultry breeding, particularly for increased egg production, and the physiology of egg production. No topics will be discussed in this bulletin which have been, or are to be treated in other bulletins of the Station.

FEEDS AND METHODS OF FEEDING.

When the new experiments in breeding were inaugurated at the Maine Station in 1907 and 1908* it seemed desirable to examine thoroughly the methods of management which had been so long used here, with the view of determining whether it might not be well to make some changes before embarking on another long period of breeding work. It is obvious that changes in management cannot be made during the course of a breeding experiment without interfering seriously with the interpretation of any results obtained. Any new methods of management, feeding, etc., which one wishes to use, must be inaugurated at the beginning of the experiment, and adhered to throughout.

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*Cf. Me. Agr. Expt. Stat., Bulletins 157, 159 and 166.

Upon reviewing the whole subject of the methods of handling poultry in operation at the Station it finally seemed advisable to make some changes. These changes were made in 1908, and have now been tried for two years. We have been so well pleased, on the whole, with these new feeds that it is proposed to publish them at this time. The following topics are here discussed:

1. Feeding the laying pullets.
2. Feeding the hens, cockerels and cocks kept over the winter for breeding purposes.
3. Green food for poultry.

FEEDING THE LAYING PULLETS.

The feed of all adult birds, whether pullets or not, consists of two essential parts: (a) the whole or cracked grains scattered in the litter, and (b) the mixture of dry ground grains which has come to be generally known as a dry mash. These two component parts of the ration and the methods of feeding them will be considered separately. In addition to the grains and dry mash, oyster shell, dry cracked bone, grit, and charcoal are kept in slatted troughs, and are accessible at all times. Plenty of clean water is furnished. About 5 pounds of clover hay cut into ½-inch lengths is fed dry daily to each 100 birds in winter. When the wheat, oats, and cracked corn are given, the birds are always ready and anxious for them, and they scratch in the litter for the very last kernel before going to the trough where an abundance of feed is in store.

It is very evident that the hens like the broken and whole grains better than the mixture of the fine, dry materials; yet they by no means dislike the latter, for they help themselves to it, a mouthful or two at a time, whenever they seem to need it, and never go to bed with empty crops, so far as noted. They apparently do not like it well enough to gorge themselves with it, and sit down, loaf, get overfat, and lay soft-shelled eggs, as is so commonly the case with Plymouth Rocks when they are given warm morning mashes in troughs.

Some of the advantages of this method of feeding are that the mash is put in the hoppers at any convenient time, only guarding against an exhaustion of the supply, and the entire

avoidance of the mobbing that always occurs at trough feeding when that is made a meal of the day, whether it be at morning or evening. There are no tailings to be gathered up or wasted, as is common when a full meal of mash is given at night. The labor is very much less, enabling a person to care for more birds than when the regular evening meal is given.

Taking first the dry grains, the following may be said in regard to the method in which they are fed: Early in the morning for each 100 hens 4 quarts of whole corn is scattered on the litter, which is 6 to 8 inches deep on the floor. This is not mixed into the litter, for the straw is dry and light, and enough of the grain is hidden so the birds commence scratching for it almost immediately. At 10 o'clock they are fed in the same way 2 quarts of wheat and 2 quarts of oats. This is all of the regular feeding that is done.

The litter which the Station now uses for its houses in preference to all others which have been tried, consists of a mixture of dry pine shavings and straw. The shavings can be obtained in this part of the country from box mills in bales, which are sold at a price of about 10 cents per bale. These shavings are spread on the floor of the pen to a depth of some 5 to 7 inches. From 6 to 8 bales will cover the floor of a pen which accommodates from 100 to 125 birds. On top of these shavings is spread a thin layer of straw. Straw which has not been baled is preferred because it is less liable to be broken and will consequently wear longer in the pen. This combination of straw and shavings gives excellent satisfaction as a litter. The straw serves the purpose of protecting the shavings so that they last a longer time than would otherwise be the case before they are finally worked up into a mass of fine material which packs down and becomes damp. The shavings become damp much less quickly than does a litter of straw alone. This is because they are finer, and the birds can keep them worked over much more thoroughly. This constantly exposes and dries out new portions of the mass of litter. Using this combination of shavings and straw it is not usually found necessary to change the litter in the pens oftener than once in three months.

It is in regard to the dry mash portion of the ration in which the changes already referred to (p. 66) have been made. The dry mash which was *formerly used* at the Station had the following composition:

	Pounds
Wheat bran	200
Corn meal	100
Middlings	100
Gluten meal or brewers' grains	100
Linseed meal	100
Beef scrap	100

The experience of the Station with this mash extending as it has over a number of years has indicated that it was somewhat too rich. The relatively large amount of such concentrated feeds as linseed meal and gluten meal seemed to make too rich a ration for the well-being of the fowls. During the years when this mash was fed more or less difficulty was always experienced with liver troubles in the birds. Birds died with all the symptoms that would be expected to come from indigestion arising from feeding too rich food.

In planning the new dry mash ration consideration was given to the physiological conditions under which the birds developed and under which they were placed in the laying houses. It is evident that the bringing of the birds in from the range upon which they have grown from little chickens, into the laying houses, is apt to be a very violent and abrupt transition. It has seemed in studying the birds in the fall of the year that this change was an important time in the life of the bird, and that the results during the subsequent winter with reference to egg production depended much upon the way the transition from range conditions to the laying house was made. It seemed advisable both on general grounds and from observation of the birds themselves to make this change as gradual as possible. With this idea in mind the pullets have been brought into the houses from the range much earlier during the past few years than was the custom before. It is the custom at the present time to bring in the pullets from the range as soon as possible after the first of September.

When the pullets are brought in as early as this it is not, of course, advisable to shut them up entirely in the houses at once. On the contrary, the work is planned in such a way that there is always a freshly seeded yard full of green grass for the birds to run in after they are brought into the house until cold

weather sets in in the fall. In other words, the birds are brought from free range into a condition of restricted range, but with better pasturage on the restricted than on free range. The yards are freshly seeded and have not been trampled down or burned and dried out by the sun, as is the grass on the open range from which the birds are taken. In this way the attempt is made to have the transition from open range conditions to house conditions as gradual as possible. After about two months, or occasionally even a little longer of restricted range, the birds are finally shut up in the curtain front house for the winter season.

Further in accordance with this idea of gradual change it is thought wise not to put the pullets which are brought in from the free range conditions abruptly on to the heavy, forced-laying mash which it seems to be necessary for them to have during the winter months if they are to do their best in the way of egg production. It has been said that a hen will not lay her best unless she is on full feeding. This is quite true, but it is probably equally true that a great deal of harm can be done to a pullet in regard to her future egg production by abruptly bringing her from free range conditions into restricted yards or to entire confinement in the house and putting her on a heavy, rich laying mash like the one which was formerly fed at this Station. On the contrary, it seems reasonable to bring the birds more gradually on to this rich ration. It is in accordance with this idea that the dry mash feed which is now used at the Station has been planned. The formulas and method of feeding this new dry mash are given below. It will be noted that the mash is made richer in successive months. These formulas are planned on the assumption that the pullets will be brought into the winter laying quarters sometime during the month of September.

Composition of Dry Mash Fed to Laying Pullets.

First month in laying house (September):—

Bran	300 lbs.
Corn meal	100 lbs.
Middlings	100 lbs.
Meat scrap	100 lbs.

Second month in laying house (October) :—

Bran	200 lbs.
Corn meal	100 lbs.
Middlings	100 lbs.
Gluten meal	100 lbs.
Meat scrap	100 lbs.

Third month in the laying house (November) :—

The mash has the same composition as that of the second month given above *with the addition of 50 pounds of linseed meal.*

Fourth month in the laying house :—

The mash has the same composition as that of the second month given above.

Fifth month in the laying house :—

The mash has the same composition as that of the third month as given above.

From this time on 50 pounds of linseed meal are put into the mash as given for the second month above every alternate month. That is to say, one month linseed meal is fed and the next month it is not.

This dry mash made as described above is kept before the birds all the time in open hoppers of the type which has been described in previous publications from this Station.*

The advantages which it is believed have resulted from this method of feeding the laying pullets are two fold: first, in the good effect on the vitality of the birds, and, second, in its effect on the evenness of egg production during the winter months. It is a fact well known to poultrymen that if pullets are too rapidly forced for egg production in the early fall there is a marked tendency for them to moult during the winter at just the time when they should be doing their best work in egg production. Since adopting the method of feeding the pullets described above, not only have the birds been much freer of digestive troubles and diseases involving the liver, but also there has been no moulting in the early winter after a short spurt of egg production in the fall months. On the contrary the egg production on this plan begins in September and gradually and steadily increases through the winter months. During the past

*See Farmers' Bulletin 357 for a description of these hoppers.

two years while this method of feeding has been used, there has been hardly a pullet in winter moult, whereas on the old system of feeding such birds were common every year.

The character of the egg production under this method of feeding is well shown in Table 1 and graphically in Figure 72.

TABLE 1.

Egg Production of 300 Barred Plymouth Rock Pullets, Fall and Winter of 1909.

MONTH.	Total number of eggs laid.	Average per bird.
September	139	.46
October	725	2.42
November	984	3.28
December	2,926	9.75
Totals	4,774	15.91

This table shows the total number of eggs and the average number of eggs per bird laid by 300 Barred Plymouth Rock pullets put into the laying house on September 1-3, 1909. These birds were intended for trap nest tests in connection with experiments in breeding for egg production. They were all pedigreed birds. It will be seen from the figures of the table that the average production made no sudden spurt in the early fall but came up gradually until in December when it rose quite rapidly at just the time of year when a high egg production is most desired. The November average of 3.28 eggs is slightly below the general average November production for the Maine Station birds over a period of 8 years.* The November average for the 8-year period was 4.63 eggs. It thus appears that the birds in 1909 laid about one egg less in November than the general average of the flocks over the long period. This defect in November, however, is offset by the favorable difference for December. The December average for the 300 birds this year, as

*Cf. Bureau of Animal Industry Bulletin 110, Part II. (In press).

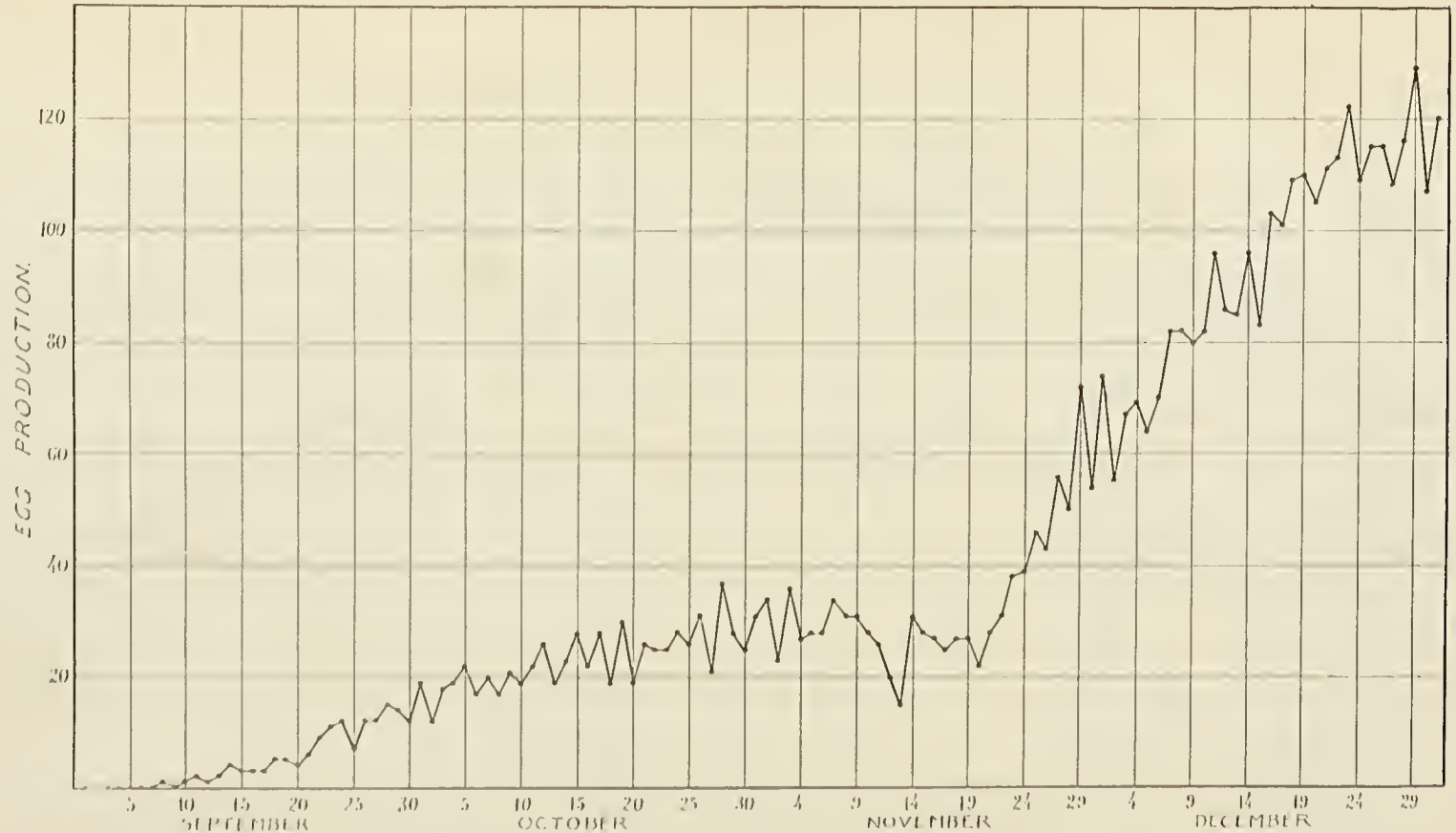


Fig. 72. Diagram showing the daily egg production of 300 Barred Plymouth Rock pullets put into the laying house at the beginning of September, 1909. The ordinates give the absolute number of eggs produced on each of the dates given along the base. This diagram includes the egg production from September 1 to December 31. If the line were to be continued it would show a decline during the month of January to be followed by a rise in the latter part of February and March.

shown in the table is 9.75, whereas the 8-year general average of the Station flocks is only 8.91. Reckoning the average net return on eggs for the four months of 1909 covered in the table to have been 40 cents per dozen, which is as near as can be estimated to what the Station actually received for these eggs, it appears that *each one of these 300 pullets had averaged to return to the Station 53 cents in eggs alone before January 1 of her pullet year.*

The facts regarding egg production are brought out by Figure 72 in another way. This diagram shows the daily egg production for each day after the birds were put into the house in September. The abscissae give the days of the month and the ordinates the number of eggs produced by the 300 pullets on each day. The daily production curve is here taken only to the end of December. It will be noted that there is a gradual and steady increase in egg production from early in the month of September until well on in November, then there is a slight decline in the curve, which from the low point reached rises very rapidly to a maximum point at the end of December. It should be said that this high point at the end of December really represents the winter maximum. From that point on the curve declines to a February minimum, which has been found to be a characteristic of egg production curves at this Station. The daily egg production curve for the fall of 1908 shows an even more steady rise from its beginning in September up to the February drop than does this curve for 1909. It is not necessary, however, to illustrate here more than the daily curve for one year, and 1909 has been chosen for the purpose.

FEEDING THE HENS, COCKERELS AND COCKS KEPT OVER THE WINTER FOR BREEDING PURPOSES.

Observations made in connection with the work of this Station, as well as a study of the literature which exists upon the subject, have led to the opinion that in order to get the best results in respect to the fertility and hatching quality of eggs it is not desirable to feed birds which are to be used as breeders the heavy laying ration which is used to force egg production during the winter months in pullets. The feeding of such rich food has a tendency, it is believed, to reduce or impair the fertility and hatching quality of the eggs. Therefore, a plan of

feeding birds kept to be used as breeders has been devised with the idea of getting over this difficulty so far as possible. This method of feeding is used for old hens, cockerels and cock birds which are kept from one season to another for breeding. The aim is to keep these birds on as light a ration as is consistent with the maintenance of good condition until just before the beginning of the breeding season when they are to be used and then to put them on a more stimulating and richer ration. The scratch food given to this breeding stock is the same as that given to the pullets, namely, corn for the first morning feed and a mixture of wheat and oats for the second feed of the day, both scattered in the litter. If, however, there is any tendency for the yearling hens kept as breeders to get unduly fat during the winter corn is not fed as a litter grain. The hens, under such circumstances, are simply given the mixture of wheat and oats at both feedings.

The dry mash used for these birds kept as breeders has the following composition:—

Bran	400 lbs.
Corn meal	50 lbs.
Middlings	50 lbs.
Meat scrap	100 lbs.

Birds kept over from one season to another are managed in the following way. The birds completing their pullet year which are to be kept as breeders are continued on the usual pullet ration until after they have finished their moult in the early fall, usually in September or early October with the birds here. Immediately after the moult is over and the hens are well feathered out they are put on the dry mash ration given above. They are fed in the way described until about a month before the beginning of their second breeding season. At this Station the breeding pens are usually mated up about the first of February. About a month before this time the birds to be used as breeders (old hens, cockerels and cocks) begin to get richer food and are quickly worked on to the regular laying ration given to the pullets as described above (pp. 69-70) for the third month of the pullet year. Usually there is added to this ration a little more meat scrap than is indicated in the formula on p. 70. This has the effect of bringing the old hens into laying condition.

It has been the experience here that this method of feeding breeders appears to help towards good fertility and hatching quality of the eggs and vigor of the chicks. Usually when fed and managed in this way the old hens do not lay at all during the fall and winter months (October 1 to February 1).

GREEN FOOD FOR POULTRY.

There is a general unanimity of opinion amongst experienced poultrymen that poultry do best upon some form of green or succulent food during the winter months. The function of such succulent food is probably largely in the nature of a digestive stimulant, rather than as an addition to the actual food constituents of the ration. Formerly mangolds were used as a source of winter succulent food at this Station. They did not, however, prove entirely satisfactory. The chief difficulty with the mangolds was found in getting them properly grown so that they would keep fresh and plump during the winter. If mangolds are not ripened off and harvested in the proper manner they will not keep through the winter but will shrivel and become unfit to use as a succulent food. In the experience of the Station it is much better not to feed any green or succulent food at all than to feed withered, shriveled mangolds which were harvested before they were thoroughly ripe.

On account of this difficulty with mangolds as a source of winter green food, the Station began in 1908 some experiments with green sprouted oats as a source of such food. Green sprouted oats have been very widely exploited in recent years as a green food for poultry. There are some so-called "poultry" systems" on the market which really consist of very little else than the use of this food. The first experiments with this material at the Station were not satisfactory. It was found difficult to get the oats to make a sufficiently quick growth. Experience here has indicated that in order to make a satisfactory green food the oats must be grown very quickly. In order to get quick growth it is necessary to have three things:—first, warmth; second, plenty of moisture; and third, sunlight. After a number of experiments to get the right combination of these three factors the plan to be described was finally worked out and has proven very satisfactory.

There is in connection with the Station poultry plant a hot water heating system which has a 3-inch out-go pipe. This out-go pipe as it leaves the heater passes along the rear wall of a small room which was formerly used as a grain storage room. To provide a place in which to sprout oats the back part of this room was partitioned off as a closet inclosing the 3-inch hot water pipe. The partition wall which forms the front of this closet consists of glass doors, made from regular storm window sash, hinged so as to swing open as an ordinary door does. These glass doors face towards the south side of the building which has a window directly in front of the doors. Throughout the day the closet gets plenty of light. The dimensions of this sprouting closet are as follows:—

Length.....9 ft. 3 inches
Depth.....2 ft. 6 inches
Height.....6 ft.

The place of shelves in this closet is taken by large, square green-house flats made of 7/8-inch stuff. These flats have the following dimensions:—

Length.....2 ft. 5 inches (inside)
Breadth.....2 ft. 5 inches (inside)
Depth.....2 inches (inside)

The length of the closet is such as just to accommodate three tiers of these flats, which slide on supports so that they can be moved in or out or turned around to suit the convenience of the operator, and the needs of the sprouting grain. These flats set 15 inches apart (i. e., vertically). There can be accommodated four rows of flats, three in a row, in the closet at one time. A number of holes are bored in the bottom of each one of the flats in order to drain off the surface moisture which comes with the wetting of the oats.

The arrangement of the sprouting closet and the flats is shown in Figs. 73 and 74.

The advantage of the closet arrangement described is that it enables one to control the three necessary factors of heat, moisture and light, quite completely. In this closet it is easily possible to maintain a temperature which does not run at any time below 70 degrees. The closet being perfectly tight it is possible

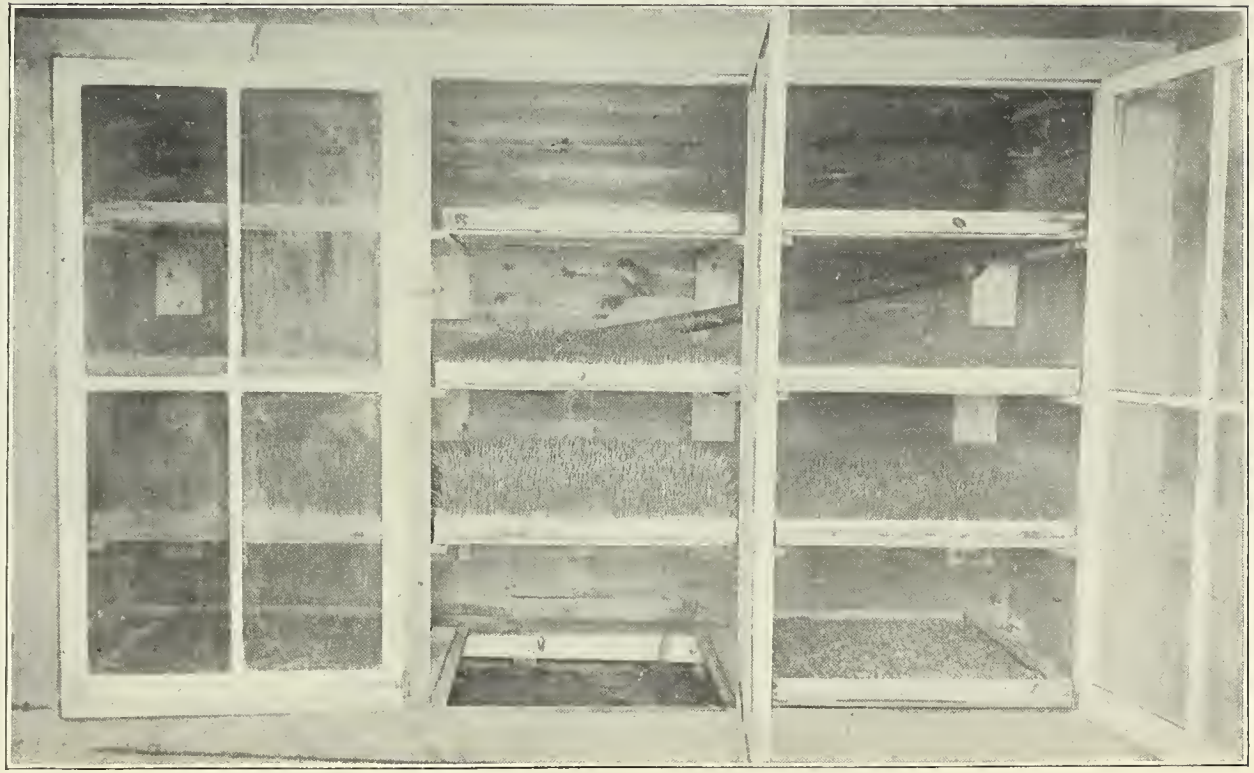
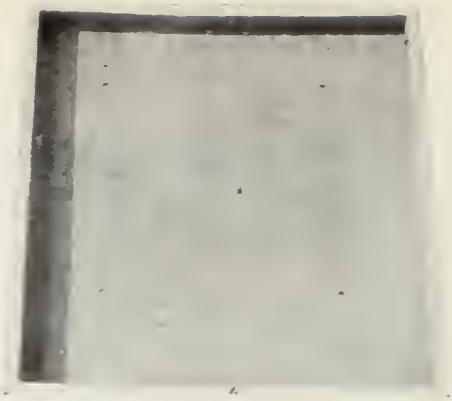
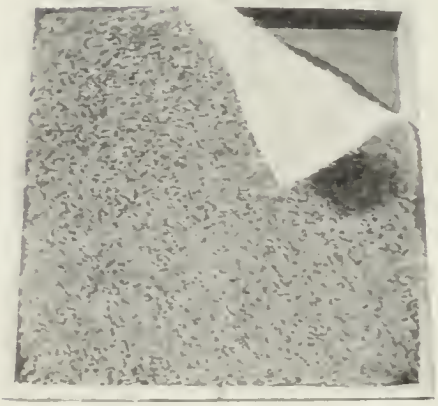


FIG. 73. Green Food Grower.



A



B

C

FIG. 74. A, empty flat. B, oats started to sprout. C, oats sprouted more.

to saturate the air with moisture quite easily and virtually convert the whole space into a great moist chamber. With this arrangement one is able to grow oats from 4 to 6 inches high in one week's time. The only difficulty with which one has to contend is the matter of mould. There is always a tendency for the oats to mould in the sprouting process. The only way in which it has been found possible to control this mould is by thoroughly cleaning the flats after each time when they are used. After a flat has been emptied it is thoroughly scrubbed with a 50 per cent. solution of formalin (that is, equal parts of commercial formalin and water). This scrubbing is very thoroughly done and sufficient formalin is used to soak the flat thoroughly. With this precaution, and if the oats are further made to grow rapidly, the mould does not give any trouble whatever.

The actual method of sprouting the oats is as follows: Clean and sound oats are soaked in water over night in a pail. The next morning flats are filled to the depth of about two inches, and put into the sprouting closet. At the beginning freshly filled flats are placed near the top of the closet so as to get the maximum amount of heat, and in that way get the sprouts started at once. During the first few days, until the sprouts have become from a half to three-quarters of an inch long, the oats are thoroughly stirred and raked over at least two or three times during the day. This stirring insures an even distribution of moisture throughout the mass of oats in the flat. After the sprouts become sufficiently long so that the oats form a matted mass it is not desirable to stir them, or to disturb them in any way. Stirring at that time will break off and injure the sprouts and the green portion above the mass will not grow so well. The matter of prime importance in growing the oats successfully has been found to be sufficient moisture. The tendency at first is to use too little moisture. The oats should be kept quite wet. The aim here is to keep condensed moisture standing on the glass doors which form the front of the closet at all times. In order to do this it is found necessary to wet the oats three times a day. This is done with an ordinary greenhouse sprinkling can, with very little expenditure of time or labor. As the oats grow the flats are moved to different positions in the closet. The taller the green material gets the nearer the flats are moved towards the floor, because the growing grain

then needs less heat. This procedure leaves the desirable places in the closet for the grain just beginning to sprout where high temperature is needed.

The oats are fed when they are from 4 to 6 inches in height. They are fed at the rate of a piece of the matted oats and attached green stalks about 6-8 inches square for each 100 birds per day. In feeding, this 6 to 8-inch square piece is broken into smaller pieces and scattered over the pen, so to ensure that all the birds shall have an opportunity to get some. Fed at the rate indicated, this material has never caused any bowel trouble among the birds.

It should be clearly understood that the purpose for which green sprouted oats are fed is their tonic and stimulative influence on the digestive organs. They are not fed for the food value of the oats themselves. If one wishes merely to feed oats they can be most economically fed not sprouted. The point of sprouting is to furnish fresh, succulent, *green* food during the winter months.

Keeping Poultry Free of Lice.

One of the most difficult and trying problems which the poultry keeper has to meet is that of keeping his poultry houses and stock reasonably free from lice, mites, and other external parasites. There are many proprietary preparations on the market designed to accomplish this end in one way or another. Most of these preparations are, in proportion to their efficiency, very expensive. Many of them have been tried at the Maine Experiment Station. The Station has finally, however, come to follow the procedure outlined in a circular, from which the present section of this bulletin is adapted, to the exclusion of all others, and with results which are extremely satisfactory. Indeed, it may be said that vermin on the poultry or in the houses no longer cause any appreciable annoyance in the work of the Station plant.

Formulae for the preparations which are in use at the Station were in the first instance given the writers of this bulletin by Mr. F. C. Lawry, formerly of the Poultry Department of Cornell University. These formulae were presented by Mr. Lawry to his classes for a number of years. The Poultry Department

of Cornell University has very kindly given its consent to the Maine Experiment Station to publish these methods for the benefit of those interested in poultry in Maine.

In keeping a poultry plant free from lice there are two points of attack: One, the birds themselves; the other, the houses, nest boxes, roosting boards, etc. For the birds themselves experience has shown that the best way to get rid of the lice is by the use of a dusting powder to be worked into the feathers. In using any kind of lice powder on poultry, whether the one described in this circular or some other, it should always be remembered that a single application of powder is not sufficient. When there are lice present on a bird there are always unhatched eggs of lice ("nits") present too. The proper procedure is to follow up a first application of powder with a second at an interval of 4 days to a week. If the birds are badly infested at the beginning it may be necessary to make still a third application. To clean the cracks and crevices of the woodwork of houses and nests of lice and vermin a liquid spray or paint is probably the most desirable form of application.

The original Lawry lice powder as described in the circular from this Station on the subject, was made by incorporating the liquid mixture of

3 parts of gasoline
1 part of crude carbolic acid

in sufficient plaster of paris to take up all the moisture. Since the publication of the circular two unforeseen difficulties have arisen regarding the practical utility of the powder as above described. In the first place a great many druggists in this State appear to have a deep-seated and ineradicable prejudice against furnishing their customers *crude* carbolic acid at any price. Reports have reached the Station of druggists making such utterly preposterous and absurd claims as that carbolic acid is a highly explosive substance, which they do not dare to handle! In the second place difficulty has arisen over the fact that there are in the drug trade three grades of crude carbolic acid. Two of these are very much weaker than the other and are quite useless for making the lice powder. The three grades are listed as follows by a reputable chemical house. These are retail prices.

Acid Carbolic, *Crude,* per gallon 25c.
Acid Carbolic, *Crude* 50-60 per cent., per gallon 40c.
Acid Carbolic, *Crude* 90-95 per cent., per gallon 50c.

To get the proper results *only the 90-95 per cent. should be used for making lice powder.* The weaker acids are ineffective.

Owing to the difficulty in getting the strong crude carbolic acid locally in this State at reasonable prices.* the Station has experimented to see whether some other more readily obtainable substance could not be substituted for it. It has been found that *cresol* gives as good results as the highest grade crude carbolic.

The directions for making the powder are now, therefore, modified as follows:

Take *3 parts of gasoline, and*
1 part of crude carbolic acid, 90-95 per cent. strength, or, if the 90-95 per cent. strength crude carbolic acid cannot be obtained take
3 parts of gasoline and
1 part of cresol.

Mix these together and add gradually with stirring, enough plaster of paris to take up all the moisture. As a general rule it will take about 4 quarts of plaster of paris to 1 quart of the liquid. The exact amount, however, must be determined by the condition of the powder in each case. The liquid and dry plaster should be thoroughly mixed and stirred so that the liquid will be uniformly distributed through the mass of plaster. When enough plaster has been added the resulting mixture should be a dry, pinkish brown powder having a fairly strong carbolic odor and a rather less pronounced gasoline odor.

Do not use more plaster in mixing than is necessary to blot up the liquid. This powder is to be worked into the feathers of the birds affected with vermin. The bulk of the application

*One report has come to the Station of a farmer being charged *$1.00 a quart* for the poorest grade of crude carbolic acid for which a rather high *retail* price is 25 cents a *gallon* as shown above! It may be said that the Station has been able to obtain carbolic acid of the grade desired from Mr. C. F. Nichols, Orono, Maine. Mr. Nichols is prepared to furnish the 90-95 per cent. crude carbolic to anyone at a price in reasonable accordance with that given above, making allowance for the cost of containers, packing, etc.

should be in the fluff around the vent and on the ventral side of the body and in the fluff under the wings. Its efficiency, which is greater than that of any other lice powder known to the writers, can be very easily demonstrated by anyone to his own satisfaction. Take a bird that is covered with lice and apply the powder in the manner just described. After a lapse of about a minute, shake the bird, loosening its feathers with the fingers at the same time, over a clean piece of paper. Dead and dying lice will drop on the paper in great numbers. Anyone who will try this experiment will have no further doubt of the wonderful efficiency and value of this powder.

For a spray or paint to be applied to roosting boards, nest boxes or walls and floor of the hen houses the following preparation is used:—*3 parts of kerosene and 1 part crude carbolic acid, 90-95 per cent. strength.* This is stirred up when used and may be applied with any of the hand spray pumps or with a brush.

If 90-95 per cent. crude carbolic acid cannot be obtained cresol may be substituted for it in this paint.

The routine methods which the Station uses in handling its stock with reference to the lice problem is as follows:—

All hatching and rearing of chickens is done in incubators and brooders. The growing chickens are never allowed to come into any contact whatever with old hens. Therefore, when the pullets are ready to go into the laying houses in the fall they are free from lice. Sometime in the late summer, usually in August or early in September, the laying houses are given a thorough cleaning. They are first scraped, scoured and washed out with water thrown on the walls and floor with as much pressure as possible from a hose. They are then given two thorough sprayings, with an interval of several days intervening, with a solution of cresol such as is described in the next section. Then the roosting boards, nests, floors and walls to a height of about 5 feet are thoroughly sprayed with the lice paint (kerosene oil and crude carbolic acid described above). Finally, any yearling, or older birds, whether male or female, which are to be kept over for the next year's work are given two or three successive dustings, at intervals of several days to a week between each application, with the lice powder described above, before they are put into the clean houses.

As a result of these methods the Station's poultry plant is at all times of the year practically free of lice.

Making Cresol Disinfecting Solution.

In Bulletin 165 of this Station directions were given for making a disinfectant for use in and about poultry houses which had as its basis the powerful germicide cresol. The method of making the compound solution of cresol described in that bulletin calls for the use of commercial potassium hydroxide or caustic potash. Since Bulletin 165 was issued correspondence has developed the fact that farmers in Maine have a good deal of difficulty in getting potassium hydroxide at a reasonable price from their druggists. The question has been frequently asked whether it would not be possible to use in place of the potassium hydroxide the ordinary commercial lye, or "potash" as it is incorrectly termed in the trade. The Station has tried experiments in making cresol soap with ordinary lye or "potash" with successful results. The following revised directions will show how the disinfecting solution can be made with the use of ordinary lye, "Babbit's potash," or other commercial "potashes" on the market.

Liquor cresolis compositus, or as it may for convenience be called, cresol soap, may be easily manufactured by any poultryman. The only requisite is a careful attention to the details in the process and a rigid following of the instructions given below. In order to make clear the reasons for the method of manufacture which will be outlined it may be well to give some account of the nature of the substance itself. The active base of cresol soap disinfecting solution is commercial cresol. This is a thick, sirupy fluid varying in color in different lots from a nearly colorless fluid to a dark brown. It does not mix readily with water, and, therefore, in order to make satisfactorily a dilute solution it is necessary first to incorporate the cresol with some substance which will mix with water and will carry the cresol over into the mixture. The commercial cresol as it is obtained, is a corrosive substance, being in this respect not unlike carbolic acid. It should, of course, be handled with great care and the pure cresol should not be allowed to come in contact with the skin. If it does so accidentally the spot should be immediately washed off with plenty of clean water. The price of commercial cresol varies with the drug market. It can be obtained through any druggist. On the day that this is written the quotation on cresol in the New York market is 24

cents per pound. In purchasing this article one should order simply "commercial cresol."

Since cresol will not mix with water some method of making it do so must be found if it is to be used as a disinfecting solution. The plan which has been adopted is to make a cresol *soap* which shall be, like other soaps, soluble in water and at the same time carry over into the solution a considerable amount of the cresol. This is done in the following way.

Measure out 3 1-5 quarts of raw linseed oil in a 4 or 5-gallon stone crock; then weigh out in a dish 1 lb. 6 oz. of commercial lye or "Babbit's potash." Dissolve this lye in as little water as will completely dissolve it. Start with ½ pint of water, and if this will not dissolve all the lye, add more water slowly. Let this stand for at least 3 hours until the lye is completely dissolved and the solution is cold; then add the *cold* lye solution *very slowly* to the linseed oil, stirring constantly. Not less than five minutes should be taken for the adding of this solution of lye to the oil. After the lye is added continue the stirring until the mixture is in the condition and has the texture of a smooth, homogeneous liquid soap. This ought not to take more than a half hour. Then while the soap is in this liquid state, and before it has a chance to harden add, with constant stirring, 8½ quarts of commercial cresol. The cresol will blend perfectly with the soap solution and make a clear, dark brown fluid. The resulting solution of cresol soap is then ready to use. This cresol soap will mix in any proportion with water and yield a clear solution.

As has been said, cresol soap is an extremely powerful disinfectant. In the Station poultry plant for general purposes of disinfecting the houses, brooders, brooder houses, incubators, nests, and other wood work, it is usually used in a 2 per cent. solution with water. Two or three tablespoons full of the cresol soap to each gallon of water will make a satisfactory solution. This solution may be applied through any kind of spray pump or with a brush. Being a clear watery fluid it can be used in any spray pump without difficulty. For disinfecting brooders or incubators which there is reason to believe have been particularly liable to infection with the germs of white diarrhea or other diseases the cresol may be used in double the strength given above and applied with a scrub brush in addition to the spray.

Studies on Hybrid Poultry.*

When the Department of Biology of this Station was organized in the summer of 1907 a part of its work, as outlined in the original plan, involved the study of inheritance in hybrid or cross bred poultry. The general purpose with which the studies in hybrid poultry were planned was primarily to investigate fundamental principles of inheritance. During the first year of the work the experiments in this direction were largely preliminary in character. A large number of crosses were made for the purpose of getting a general view of the behavior in inheritance of some of the characters seen in the common breeds of domestic poultry. As a result of these preliminary experiments it was finally decided to undertake a thorough investigation of the reciprocal crosses of the Cornish Indian Game and Barred Plymouth Rock breeds. The detailed study of these reciprocal crosses was then begun in 1908. The present paper is a report on some of the results which have been obtained in this study up to the present time.

There were a number of reasons why this particular cross of Barred Plymouth Rock and Cornish Indian Game was chosen for detailed study. In the first place these two breeds of fowls are strikingly different from each other in a wide variety of characters. Some of the points of difference are indicated in Table 2.

The general characteristics of the two breeds crossed are shown in Figs. 75 and 76. Figure 75 gives a representation of a male and female Barred Plymouth Rock, and Fig. 76 of male and female Cornish Indian Games. Unfortunately the photographs of the Cornish fowls are not altogether satisfactory. The ruffled appearance of the feathers in the male is not characteristic, and appears in this photograph only because the wind was blowing when it was taken.

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*Papers from the Biological Laboratory of the Maine Agricultural Experiment Station, No. 21.

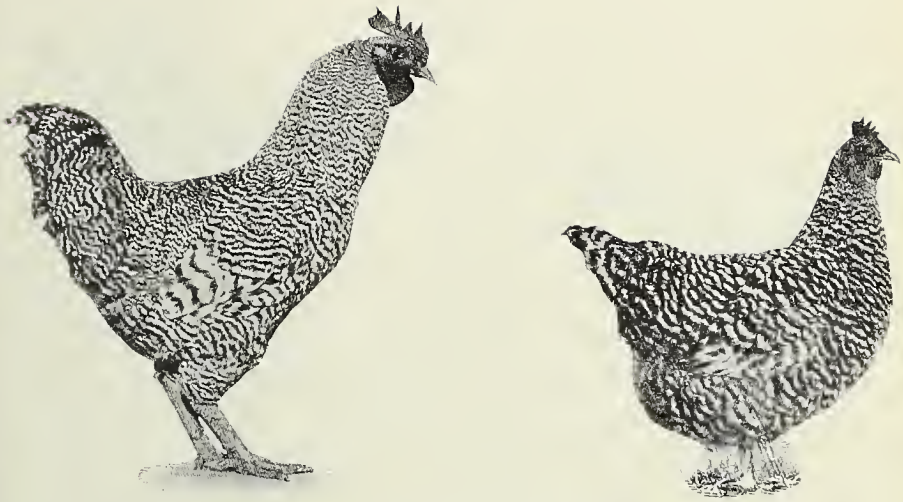


FIG. 75. Barred Plymouth Rock. Male and female.

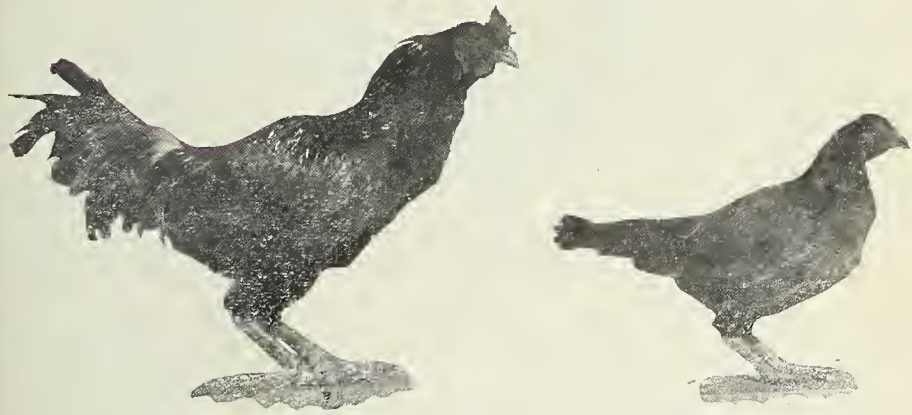
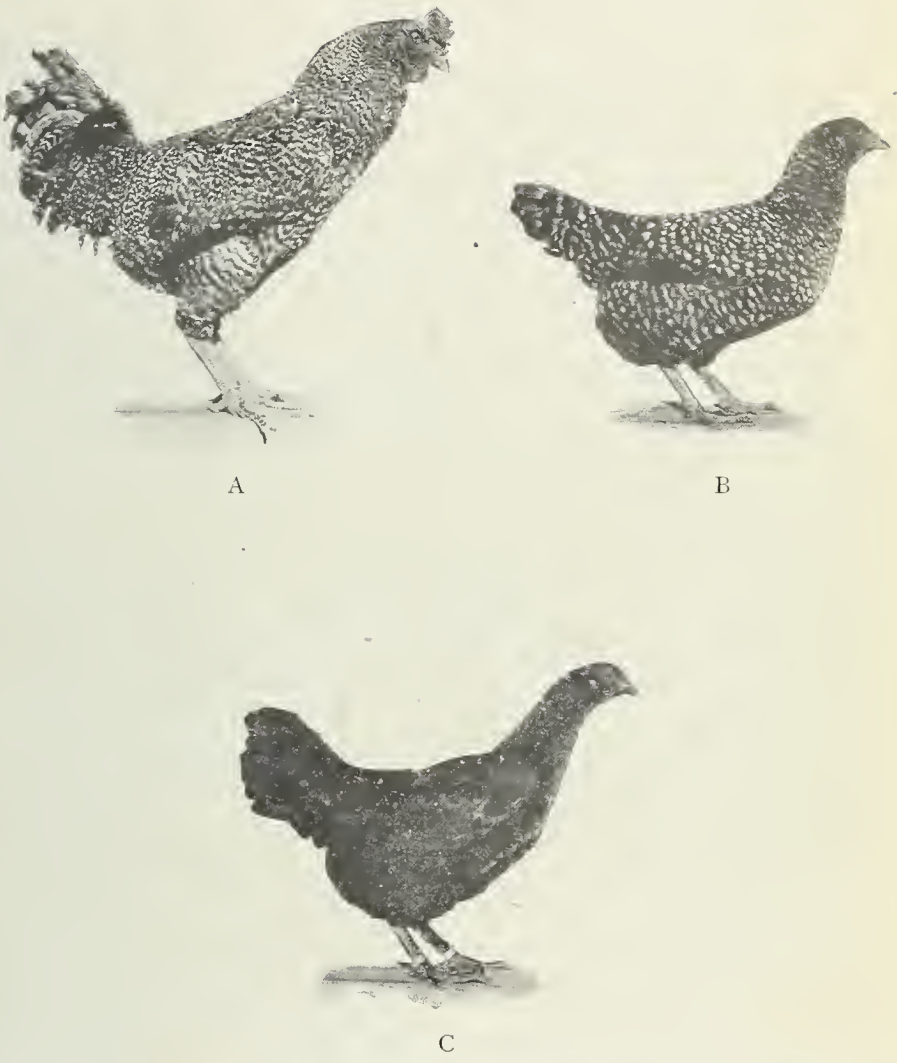


FIG. 76. Cornish Indian Game. Male and female.



A B C

FIG. 77. Hybrids between Barred Plymouth Rocks and Cornish Indian Games. A. Male bird. The males from the cross and its reciprocal are alike in appearance. B. Barred female (from Barred Plymouth Rock male and Cornish Indian Game female). C. Black female (from Cornish Indian Game male and Barred Plymouth Rock female).

TABLE 2.

Summary Statement of Typical Condition of Characters of Barred Plymouth Rocks and Cornish Indian Games.

CHARACTER.	Condition in Barred Plymouth Rocks.	Condition in Cornish Indian Games.
Comb	Single	Pea.
Wattles	Moderately long	Very scant.
Beak	*Yellow* (sometimes marked with horn colored stripes or patches.)	*Yellow* (often marked with *brown* or horn colored stripes or patches).
Eyes	Bright *red* or *bay*	*Yellow*, or approaching pearl.
Breast	*Medium* breadth. Sternum relatively *long*. Medium amount of breast meat.	Very *broad*. Sterum relatively *short*. Large amount of breast meat.
Back	Curve from neck to tail slightly *concave*.	Curve from neck to tail slightly *convex*.
Hackle feathers	*Abundant*, falling well over the shoulders and giving the neck a full appearance.	Rather *short* and *closely set*, giving the neek a neat, spare appearance.
Saddle feathers (in male)	Abundant and *long*	Rather *short*.
Body	Relatively *long*, and flattened in the dorsoventral plain.	Relatively *short*, and *round*. *Less* flattened.
Fluff	Moderately full	Not full. Feathers set close into body, giving it a neat "tucked up" appearance.
Shanks	Yellow, sometimes dusky or spotted with black pigment	Yellow or dusky yellow.
Plumage color	Barred in all sections. Basic pigment a bluish black or dark slate. See special description in American Standard of Perfection, pp. 205–208.	Non-barred. Basic pigments, black, red or bay, mahogany. See special description below (p. 86).
Tail	Carried relatively *high* well spread.	Carried relatively *low*. Compact.
Carriage	Less erect	More erect.
Winter egg production	*Good* Nov.–March mean, 1908–09. 26.53 ± .65.	*Poor*. Nov.–March mean, 1908–09. 14.92 ± 1.58.
Egg color	Deep reddish or pinkish brown. Greater saturation of color.	Pure yellowish brown. Less saturation of color.
Egg size	Relatively large. Pullets means: Length=56.322 ± .076 mm. Breadth=41.917 ± .044 mm. *Volume=51.880 ± .135 c. c.	Relatively small. Pullet means: Length=52.61 ± .35 mm. Breadth=40.43 ± .23 mm. *Volume=44.84 ± .86 c. c.
Egg shape	Relatively long and pointed. Mean length-breadth index for pullets=74.522 ± .120.	Relatively short and round. Mean length-breadth index for pullets=76.86 ± .30.
Chick down	*Black*, or very dark gray, with some creamy white parts	*Creamy yellow* below, with well marked mahogany or seal brown pattern on back.
Skin	Yellow and relatively thick	Yellow, and relatively thin.

*Calculated from the formula $V_{egg} = 4.1888\ (\frac{1}{2}\ \text{breadth})^2 \times (\frac{1}{2}\ \text{length})$.

The plumage color of the Cornish Indian Games requires more detailed consideration. The following description, adapted from the American Standard of Perfection (pp. 205-208) is taken from another paper.*

Color of Cornish Indian Games.

MALE.	FEMALE.
Head: Plumage black.	*Head:* Plumage black or black penciled with bay, approaching mahogany.
Neck: Hackle, glossy and greenish black; shafts red; plumage other than hackles, rich, glossy black.	*Neck:* Hackle glossy black, with bay shaft to each feather, the black greatly predominating; plumage other than hackle, ground color bay, approaching mahogany, each feather having two pencillings of lustrous black, the pencillings following contour of web of feather.
Back: Glossy greenish-black and dark red intermixed, the black greatly predominating; saddle feathers like the back in color, but with a somewhat larger proportion of dark red.	*Back, Breast, Body, Wing-Bows, Wing-Coverts* and *Tail-Coverts:* Ground color bay, approaching mahogany, each feather having two pencilings of lustrous black, the pencilings following contour of web of feather.
Breast: Rich, glossy black, free from any other color.	
Body and *Stern:* Black.	*Stern:* Black, or black tipped with bay.
Wings: Wing fronts, black; wing bows, glossy greenish-black and dark red intermixed the black greatly predominating; coverts forming wing bars, metallic black; primaries, black, except a narrow edging of bay on outer web; secondaries, upper web black lower web about ¼ black next to shaft of feather, the remainder being bay.	*Wings:* Primaries, black except a narrow edging of irregularly penciled bay upon outer part of web; secondaries upper web black next to shaft of feather, with a broad margin of irregularly penciled bay.
Tail: Black; sickles and coverts, glossy greenish-black.	*Tail:* Main feathers, black or irregularly penciled with bay.

Barred Plymouth Rocks and Cornish Indian Games present two extremes from the utility standpoint. This affords another important reason why this particular cross was chosen for intensive study. The Cornish Indian Game is a "meat type" bird *par excellence*. It has long been noted as one of the best breeds of poultry for meat producing purposes, particularly when crossed with other breeds. The Plymouth Rock, on the other hand, while a general purpose fowl, has been more particularly bred for its egg producing qualities. One of the objects held in mind in undertaking the work was to see in how far it might be possible to recombine, in accordance with Mendelian principles, the utility characters of these two breeds.

The purpose of the present paper is to give an account of some of the results of this hybrid work in the F1, or first hybrid generation.

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*Pearl, R. and Surface, F. M. On the Inheritance of the Barred Color Pattern in Poultry. Roux's Archiv. (In press).

SOURCE OF BREEDING STOCK USED.

In regard to the stock used in the experiments (obviously a matter of the highest importance in all Mendelian experimentation) the following may be said: The Barred Plymouth Rock stock used was that which has been bred at this Station for many years. The general breeding history of these birds is known for a period of more than 25 years. For a period of nearly ten years before the present experiments were begun they had been "line-bred," i. e., no new "blood" had been introduced into the flock from outside. The Cornish Indian Game foundation stock was reared from eggs purchased from Mr. W. S. Templeton, of Illinois, who is conceded by American poultry fanciers generally to have a strain of Cornish fowls of a high degree of excellence. The source of this stock gives assurance that it is strictly "pure-bred" in the fancier's sense, and furthermore is of superior quality as judged by the fancier. This stock, in other words, carries the characters which belong to the breed in their *typical* condition.

THE COLOR OF THE HYBRIDS.

The inheritance of color and color pattern in these hybrids has already been discussed in detail in another paper.* It will therefore not be necessary here to do more than outline the general facts regarding color inheritance, referring the reader to the paper cited for details. The essential facts are as follows:—

When the mating is to the type

Barred Plymouth Rock male x *Cornish Indian Game female*

the offspring are *all barred,* regardless of their sex.

When, on the other hand, the mating is of the type

Cornish Indian Game male x *Barred Plymouth Rock female*

the *male* chicks resulting from the cross are *barred*, and the *female* chicks are *not barred* but instead are solid black in color.

The character of the different kinds of hybrid birds obtained is shown in Fig. 77. This shows a hybrid male and barred and black hybrid females.

The actual numbers of the different kinds of *adult* hybrid birds obtained in the experiments are given in the following table, which is condensed from the more complete tables given in the detailed paper (*loc. cit.*)

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*Pearl, R., and Surface, F. M. *loc. cit.*

TABLE 3.

Showing the Sex and Color Pattern of Hybrids Obtained by Reciprocally Crossing Barred Plymouth Rocks and Cornish Indian Games.

MATING.	Total offspring.		ADULT OFFSPRING.			
			Barred.		Non-barred Black.	
	Males.	Females.	Males.	Females.	Males.	Females.
Barred Rock ♂ x Cornish ♀	112	111	70	68	–	–
Cornish ♂ x Barred Rock ♀	127	124	95	–	–	96
Totals	239	235	165	68	–	96

It is clear that we have here a case of sex limited inheritance, in which a character is correlated with sex in a definite manner. It was suggested some time ago by Spillman* that barred color pattern in poultry would be found to be inherited in this sex limited manner. This suggestion has been tested and, in a brief preliminary paper, confirmed by Goodale.**

A Mendelian hypothesis, which may or may not be true, has been put forth by Spillman (*loc. cit.*) to account for facts regarding the inheritance of barring given above. This hypothesis has been stated in briefest form by Goodale (*loc. cit.*) as follows: "The barring factor and sex in poultry are correlated in such a way that the female is always heterozygous in respect to sex and also barring when present. The male, on the other hand, is always homozygous in respect to sex and may be either homozygous or heterozygous in respect to barring." Further, it is assumed that "femaleness" and the barring factor do not exist together in the same gamete. This can be easily represented symbolically.

*Spillman, W. J. Barring in Barred Plymouth Rocks. Poultry, Vol. 5, No. 11, August, 1909, pp. 7, 8.

——— Spurious Allelomorphism: Results of Some Recent Investigations. Amer. Nat. Vol. XLII, pp. 610-615, 1909.

**Goodale, H. D. Sex and its Relation to the Barring Factor in Poultry. Science, N. S., Vol. 29, No. 756, pp. 1104, 1105, 1909.

Let F denote "femaleness," i. e., the ♀ sex character.

Let f denote absence of F (i. e., "maleness" by difference, as it were).

Let B denote the barring factor.

Let b denote the absence of B.

Then a pure B. P. R. ♂ has the gametic formula $Bf \,.\, Bf$

and " " B. P. R. ♀ " " " " $bF \,.\, Bf$

" " " C. I. G. ♂ " " " " $bf \,.\, bf$

" " " C. I. G. ♀ " " " " $bF \,.\, bf$

Then the mating B. P. R. ♂ x C. I. G. ♀ would be symbolically

$Bf.Bf \times bF.bf = Bf.bf$ (barred ♂) $+ Bf.bF$ (barred ♀)

the offspring of both sexes being heterozygous with reference to barring.

The reciprocal mating is symbolically

$bf.bf \times bF.Bf = bf.Bf$ (barred ♂) $+ bf.bF$ (non-barred ♀)

the non-barred ♀ offspring being homogygous with regard to the absence of barring.

It is evident, without further discussion, that the experimental results set forth above are, so far as they go, precisely what we should expect to get if Spillman's hypothesis is correct. In so far they support that hypothesis. They do not, of course, demonstrate that another hypothesis might not be devised which would fit the facts equally well.

The barred pattern obtained in these hybrids is not the same as that exhibited by the parent Barred Plymouth Rock stock. A detailed description of the points in which the hybrids differ in color from the parent stock is given in the complete paper and cannot be repeated here. Some of these points of difference are shown in Fig. 78.

Sex-limited inheritance, in which a particular somatic character is correlated with sex in a definite way, is now known to occur in a number of cases. In poultry we have besides the inheritance of barring as worked out by Spillman, Goodale and the present writers, and on the other hand, the inheritance of "Bankiva" and "Brown-red" color pattern in game bantams

recently described by Hagedoorn,* the inheritance of shank color and the case of the silky fowl as described by Bateson.** etc. Bateson (*loc. cit.*) devotes a chapter in his recent book on heredity to a discussion of these known cases of sex-limited inheritance.

In the remainder of this paper the hybrid pullets will, for the sake of convenience, be designated as either "barred hybrids" or "black hybrids."

THE HATCHING, MORTALITY AND SEX OF THE HYBRIDS.

The hatching records for the matings which produced the hybrids are given in Tables 4 and 5. These data are of interest chiefly from the standpoint of the physiology of reproduction. It is well known that in many cases in plants it is possible to make a cross in one direction, while the reciprocal cross entirely fails to produce offspring. In other cases the fertility is greatly reduced in the cross in one direction as compared with the reciprocal. Is there any relation of this kind in the crosses of poultry with which this paper deals? The data in the following tables are of interest in this connection. It should be said that all of the mated females, whether Barred Rocks or Cornish, were pullets. The male birds were cockerels. All were under the same conditions during the mating season, and had the same food and treatment. The eggs were all incubated in the same type of incubators, under uniform conditions. For the sake of comparison a table (Table 6) giving the hatching records of pure Cornish Indian matings is included. In all of these tables "Percent hatched" means percent of fertile eggs hatched.

In the cross Cornish Indian Game ♂ x Barred Plymouth Rock ♀, the data for which are given in Table 4, two different males were used with the same females in the course of the breeding season. The matings with the two different cockerels are separated in the table, and each group is summed and averaged by itself.

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*Hagedoorn, A. L. Mendelian Inheritance of Sex. Roux's Archiv. Bd. 28, pp. 1-34, 1909.

**Bateson, W., Mendel's Principles of Heredity. Cambridge (Univ. Press). 1909.

TABLE 4.

Hatching Records for the Mating C. I. G. ♂ x B. P. R. ♀.

MATING NUMBER.	Eggs set.	Eggs infertile.	Percent infertile.	Died in shell.	Percent of fertile eggs dying in shell.	Hatched.	Percent hatched.	Number of different incubators.
443	51	1	2	11	22	39	78	5
444	25	1	4	10	42	14	58	3
445	49	1	2	7	15	39	81	5
446	11	0	0	2	18	9	82	2
447	12	9	75	1	33	2	66	2
448	22	13	59	5	56	4	44	3
449	23	13	57	4	40	6	60	3
451	6	1	16	2	40	3	60	1
452	10	5	50	2	40	3	60	2
458	15	10	67	2	40	3	60	2
460	27	6	22	5	24	15	72	3
461	19	6	32	4	31	8	62	3
Totals and means	270	66	25	55	27	145	71	-
587	21	0	0	5	24	16	76	3
588	20	8	40	6	50	6	50	2
589	27	1	4	4	15	22	85	3
591	19	9	47	6	60	4	40	3
593	10	1	10	2	22	7	78	2
594	17	1	6	5	31	11	69	3
595	29	1	4	11	39	17	61	3
596	25	3	12	9	41	12	55	3
597	13	0	0	5	38	8	62	2
598	22	0	0	16	73	5	23	3
599	23	2	9	9	43	12	57	3
600	25	13	52	9	75	7	58	3
601	33	22	67	1	10	10	91	4
Totals and means	284	61	21	88	39	137	62	-
Grand totals and means.	554	127	24	143	33	282	66	-

TABLE 5.

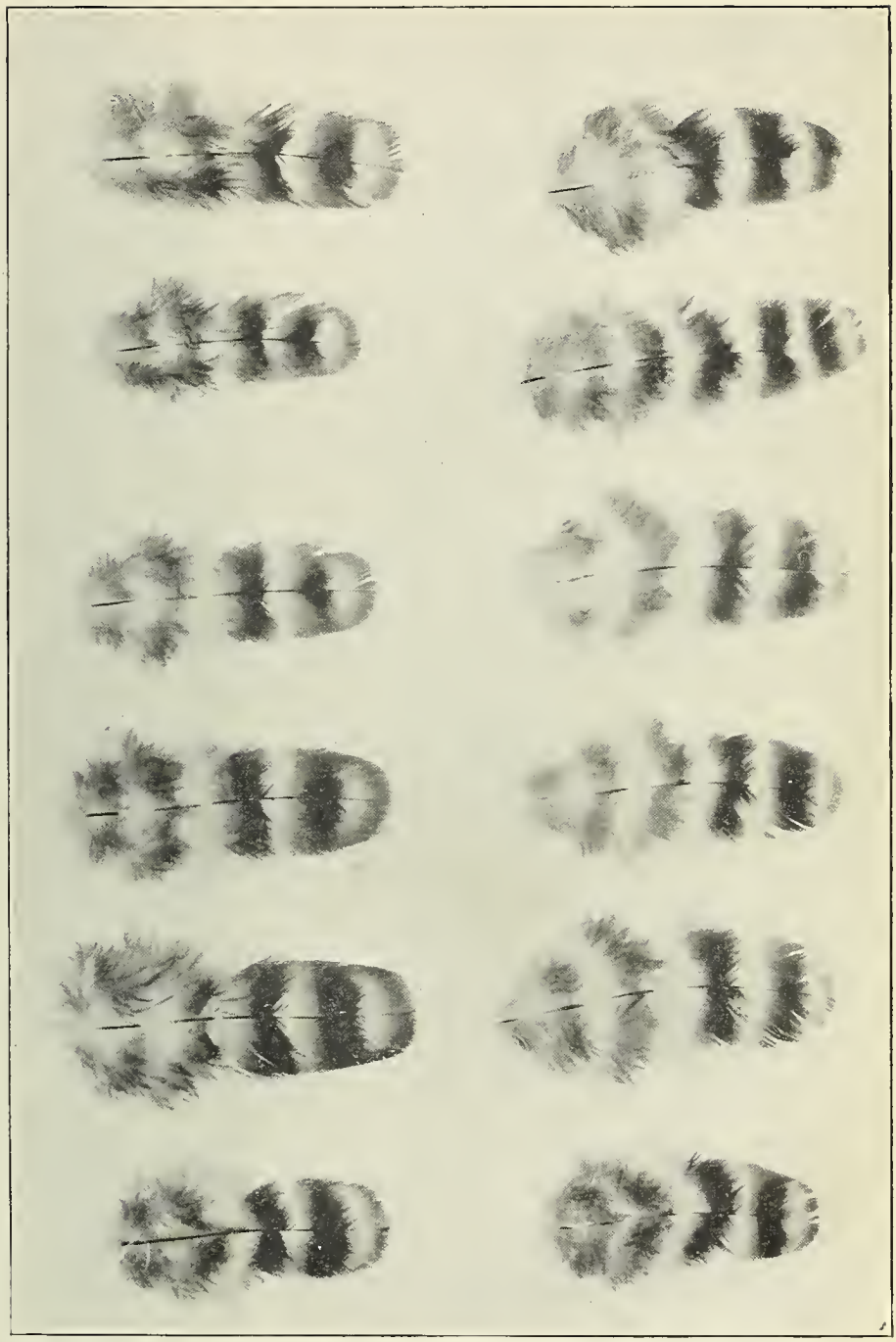
Hatching Records for the Mating B. P. R. ♂ x C. I. G. ♀.

MATING NUMBER.	Eggs set.	Eggs infertile.	Percent infertile.	Died in shell.	Percent of fertile eggs dying in shell.	Hatched.	Percent hatched.	Number of different incubators.
418	26	0	0	10	38.0	16	62	3
419	25	1	4	5	21.0	17	71	2
420	18	1	6	13	76.0	4	24	3
421	31	2	6	12	29.0	17	59	2
422	37	0	0	6	16.0	31	84	5
423	33	0	0	14	42.0	19	58	4
424	52	7	13	4	9.0	39	87	6
425	23	0	0	6	26.0	17	74	3
426	24	0	0	5	21.0	19	79	3
427	22	0	0	2	9.0	20	91	3
428	46	2	4	10	23.0	34	77	5
429	20	1	5	3	16.0	16	84	3
Totals and means..	357	14	4	90	26.0	249	73	-

TABLE 6.

Hatching Records for Pure Cornish Indian Game Matings. (C. I. G. ♂ x C. I. G. ♀).

MATING NUMBER.	Eggs set.	Eggs infertile.	Percent infertile.	Died in shell.	Percent of fertile eggs dying in shell.	Hatched.	Percent hatched.	Number of different incubators.
430	32	1	3	4	13	27	87	5
431	19	2	11	4	24	12	71	4
432	46	2	4	23	52	21	48	3
433	32	1	3	9	29	22	71	3
434	48	2	4	10	22	36	78	4
435	35	2	6	9	27	24	73	3
436	26	0	0	6	23	20	77	3
437	45	8	18	36	97	1	3	3
438	23	3	13	5	25	15	75	3
439	54	9	17	40	89	5	11	4
440	19	7	37	6	50	6	50	3
567	38	4	11	15	44	19	55	4
Totals and means..	417	41	10	167	44	208	55	-



A B

FIG. 78. Feather Chart, showing feathers from Barred Rock female and Barred hybrid female. A. feathers from hybrids. B. feathers from Barred Rocks.

From these tables the following points are to be noted:—

1. The fertility of the eggs during the hatching season in which these hybrids were raised was relatively very high for the pure bred birds, both Barred Plymouth Rocks and Cornish Indian Games. The average percentage of eggs infertile from all the Barred Plymouth Rock pullets used as breeders during that breeding season was 13.65 ± 1.38.* The average percentage of eggs infertile for the pure Cornish Indian Game matings shown in Table 6 above is only 10. In both cases (Barred Rocks and Cornish) the figures given include all the eggs set throughout the whole of the hatching season from early in March until the middle of May. No data were omitted in making up these general averages. It is evident from these average figures of 13 percent and 10 percent of infertile eggs that (a) the environmental conditions were favorable for securing high fertility of eggs during the hatching season of 1909 and (b) that the breeding stock of both pure breeds was vigorous and in good condition. It is doubtful whether fertility records sensibly lower than 10 percent of infertile eggs for the whole hatching season can be expected with large flocks of birds.

2. It will be noted from Tables 4 and 5 that the percentage of eggs infertile in the hybrids was quite different according to the direction in which the cross was made. In the case of the cross considered in Table 5 (Barred Rock ♂ x Cornish ♀) the percentage of eggs infertile is very low, amounting to only 4 percent for the whole season. This, it will be noted, is a better average result than was obtained with either the Barred Rocks or Cornish Indian Games when pure bred during the same season, and kept under the same environmental conditions throughout. On the other hand, the fertility of the eggs in the reciprocal mating (Cornish Indian ♂ x Barred Rock ♀) was very much reduced, as is shown in Table 4. Taking the whole season through and averaging the results obtained from two different male birds used in this cross the percentage of eggs infertile is 24. This is six times as great a percentage of infertility as was obtained in the other cross, and is practically twice as great as the highest percentage

*Cf. Me. Agric. Exp. Station Bulletin 168, Table VI, p. 119.

of infertility obtained from either of the pure matings of the two breeds entering into the cross during the same hatching season.

It seems unlikely that this considerable reduction in fertility of eggs in the cross Cornish ♂ x Barred Rock ♀ was due to poor quality of the male birds used. The reason for this opinion lies in the first instance in the fact that two different male Cornish birds were used and both gave almost identical results. Both were first rate specimens in all particulars so far as could be told by external appearances. They were certainly vigorous birds. This being the case it seems remarkable that both should have shown so nearly the same degree of infertility of eggs. On the other hand the result does not appear to be due to the inclusion in the pen of a number of particularly bad individual females that were incapable of making high fertility records. While in both halves of Table 4 there are individual females with extremely poor records as to fertility of eggs, it is nevertheless the fact that the birds which gave bad results with one of the cockerels are not the same ones that gave bad results with the other, as would be expected to be the case if the fault were primarily with the female birds.

A suggestion which occurs to one in this connection is that the Cornish Indian spermatozoa do not find the Barred Plymouth Rock oviduct so favorable an environment as they do the Cornish Indian oviduct. It is a well known fact that in gallinaceous birds the spermatozoa from one copulation fertilize a number of eggs. In order that this may occur the spermatozoa must live and remain in vigorous condition in the oviduct of the female for a considerable period of time. In the present instance there may be a lowering of the vitality of the Cornish Indian spermatozoa due to a lack of adaptation to the conditions presented by the Barred Rock oviduct. The significant factors in such a case would probably be of a chemical character. It is conceivable that the secretion of the Barred Rock oviduct may be too acid or too alkaline to give the best results for the Cornish Indian spermatozoa. Obviously the present data are not sufficiently extensive to give any conclusive evidence in regard to this suggestion. The great difference in the fertility of eggs in the crosses made in the two different directions is, however, of interest and deserves further investigation.

3. Turning now to the consideration of the hatching quality of the eggs in the two different crosses, it appears to be the case in the present statistics that the *fertile* eggs of either Barred Plymouth Rock or Cornish Indian Game females are more likely to *hatch* if they are fertilized with spermatozoa of the other breed than if they are fertilized with their own spermatozoa. That is to say, in these experiments the percentage of fertile eggs hatched was higher for the cross fertilized eggs than for either of the pure breeds under the same environmental conditions, regardless of the direction of the cross. The data in the case are as follows: For the Barred Plymouth Rock pullets in the whole breeding season of 1909, the average percentage of fertile eggs hatched was 47.67 ± 1.80.* The pure matings of Cornish Indian Games in the same season gave an average of 55 percent of fertile eggs hatched, as shown in Table 6. For the hybrids, as shown in Tables 4 and 5, the average figures of the whole season are 73 percent of fertile eggs hatched for the cross in one direction (Barred Plymouth Rock ♂ x Cornish Indian Game ♀) and 66 percent of fertile eggs hatched in the reciprocal cross. In other words, the *hybrid* germ cell (fertilized ovum) appears to possess greater developmental vigor than does the *pure* germ cell. This is shown not only in the greater viability of the eggs during incubation, but also in other ways. These hatching records, however, furnish a novel kind of evidence of the well known phenomenon of greater vigor in hybrids.

4. The "percentage of fertile eggs dying in the shell" is obviously the arithmetic complement of the "percentage of fertile eggs hatched" and does not need particular discussion.

We may turn next to a consideration of the mortality and sex ratio records. The data for all hybrid chickens hatched in the whole season are given in Table 7, while the data for all chickens hatched in the season for pure matings are in Table 8. In order to save space detailed data for each individual mating are not given in the case of the pure bred chicks.

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*Cf. Me. Agr. Exp. Sta. Bulletin 168, Table VI, p. 119.

TABLE 7.

Showing the Sex Ratio and Mortality Records of All Hybrid Chicks. Season of 1909.

BARRED ROCK ♂ X CORNISH ♀.							CORNISH ♂ X BARRED ROCK ♀.						
Mating number.	Total chicks.		Chicks died.		Percentage mortality.		Mating number.	Total chicks.		Chicks died.		Percentage mortality.	
	♂	♀	♂	♀	♂	♀		♂	♀	♂	♀	♂	♀
418	5	9	4	6	80	67	443	10	14	10	7	100	70
419	5	9	2	2	40	22	444	6	6	0	2	0	33
420	2	0	0	0	0	0	445	16	19	5	5	31	26
421	8	7	0	1	0	14	446	3	5	0	0	0	0
422	15	15	6	5	40	33	447	2	0	0	0	0	0
423	6	12	2	2	33	17	448	2	2	1	1	50	50
424	20	16	8	4	40	25	449	3	3	0	0	0	0
425	9	6	2	0	22	0	451	2	1	0	0	0	0
426	8	10	3	4	38	40	452	2	1	0	0	0	0
427	11	7	4	5	36	71	458	0	3	0	0	0	0
428	14	16	12	12	86	75	460	9	6	0	1	0	17
429	9	4	5	3	56	75	461	8	8	2	0	25	0
							Totals	72	63	18	16	25	25
							587	4	3	1	1	25	33
							588	1	2	1	1	100	50
							589	11	11	0	2	0	18
							591	1	3	1	1	100	33
							593	4	3	0	0	0	0
							594	2	3	1	2	50	67
							595	6	10	1	4	17	40
							596	6	6	2	1	33	17
							597	2	5	0	0	0	0
							598	2	3	1	2	50	67
							599	7	5	2	2	29	40
							600	2	4	1	2	50	50
							601	7	0	3	0	43	0
							Totals	55	64	14	20	25	31
Grand totals.	112	111	48	44	43	40	Grand totals.	127	124	32	36	25	29

TABLE 8.

Showing the Sex Ratio and Mortality Records of All Pure Bred Chicks Hatched from Pullet Eggs. Season of 1909.

MATING.	Number of different matings.	Total chicks.		Chicks died.		Percentage mortality.	
		♂	♀	♂	♀	♂	♀
Barred Plymouth Rock ♂ and ♀ ..	111	664	698	278	238	43	34
Cornish Indian Game ♂ and ♀....	12	59	76	26	29	44	38

From these tables the following points are to be noted:

1. In both hybrid matings a few more males than females were produced. The differences, however, are so small as to be insignificant. Practically an equal absolute number of males and females were produced in the hybrid matings. In the pure matings on the other hand there is a distinct and significant preponderance of females in both matings.

2. It appears then to be the case that there is a tendency shown in the 1971 chicks here under consideration for *relatively* more males to be produced in hybrid than in pure matings. This result is in accord with a suggestion made by Davenport* in the following words (p. 97): "There is a widely held and frequently expressed opinion that hybrids show an excessive proportion of males." No support was given to this suggestion by Davenport's own published statistics. His general conclusion was that, "The exceptions to the law of equality of sexes in hybrid offspring are . . . . individual and not of general significance." It was subsequently shown* that there is an excess of males produced when certain human stocks are cross bred as compared with the same stocks bred pure.

The real test of whether the present poultry statistics definitely bear out the same conclusion must come from an examination of the probable errors of the sex ratios involved. Taking the sex ratio as the percentage of males in the total number of offspring we have the usual expression for the probable error of a proportion

*Davenport, C. B. Inheritance in Poultry. Carnegie Institution of Washington, Pbl. No. 52, 1906.

*Pearl, Maud D. and R. On the Relation of Race Crossing to the Sex Ratio. Biol. Bulletin, Vol. 15, No. 4, pp. 194-205. 1908.

$$P.\ E.\ ratio = .67449\ \sqrt{pq/n}.$$

where p = percentage of males, q = percentage of females ($= 100 - p$), and n = the total number.

Applying this formula to the data in Tables 7 and 8 we have the following results:—

Percentage of males amongst all hybrids	50.42 ± 1.55
Percentage of males amongst all pure Barred Rocks	$48.75 \pm .91$
Percentage of males amongst all pure Cornish	43.70 ± 2.88
Difference in proportion of males between hybrids and Barred Rocks	1.67 ± 1.80
Difference in proportion of males between hybrids and Cornish	6.72 ± 3.27

It thus appears that 1 2-3 percent. more males are produced in hybrid than in pure Barred Rock matings, and 6.72 percent more than in pure Cornish matings. The probable errors are of such magnitude, however, that it cannot be asserted that these differences are significant. The data are of interest in so far as their general trend is concerned, however, and will be of value, in connection with further material to be collected in the future, in helping to settle this particular phase of the problem of sex-determination.

3. The chick mortality, both absolute and percentage, is substantially equal in the two sexes in the case of the hybrids.

4. In the case of the pure bred chicks the percentage mortality is distinctly higher for the males than for the females, in both breeds. No reason for this marked difference in the mortality rate of the sexes in pure bred birds is apparent. Nor is it clear why there is a difference between hybrid and pure bred birds in this regard. It is idle to discuss the various speculations regarding the possible cause of this relation which come to one's mind until more ample data can be had.

5. The mortality shown in Tables 7 and 8 is absolutely high. These tables give in that respect an entirely wrong impression of the general vigor and vitality of the chicks raised in the spring of 1909. The reason why the mortality figures are so high in these tables has little relation to the real quality of the chicks themselves. The high mortality originates from the results of one hatch. On April 21, 1909, a large hatch (between 600 and 700 chicks) was brought off. These chicks

were as promising looking a lot when they came from the incubators as any hatched during the season. They were a strong and vigorous flock. No one of them, so far as we know, died from an infectious disease, like white diarrhœa. Yet practically every chick in this hatch died, and that within four weeks of hatching. They were fed by a man without any previous experience in feeding Barred Rock chickens under our conditions of brooding, etc. In spite of repeated instructions the birds were over fed to the point where it became impossible to save any of them. The effect of this one hatch on the total mortality records is shown in Table 9.

TABLE 9.

Showing the Sex Ratio and Mortality Records of Chicks, with the Hatch of April 21, 1909, Omitted.

MATING.	Total chicks.		Chicks died.		Percentage mortality.	
	♂	♀	♂	♀	♂	♀
Barred Rock ♂ x Cornish ♀	88	84	31	25	35	30
Cornish ♂ x Barred Rock ♀	116	114	25	31	22	27
Barred Rock ♂ x Barred Rock ♀	506	548	90	81	18	15
Cornish ♂ x Cornish ♀	51	56	20	13	39	23

The great reduction of mortality, especially among the Plymouth Rocks, is apparent. More than a half of the total mortality of the whole season among Plymouth Rock chicks resulted from this one hatch.

6. Taking the corrected figures of Table 9 as a basis it appears to be the case (a) that hybrid chicks from Cornish eggs (mating B. P. R. ♂ x C. I. G. ♀) showed about the same percentage mortality as pure Cornish chicks; and (b) that hybrid chicks from Barred Rock eggs (mating C. I. G. ♂ x B. P. R. ♀) showed about the same percentage mortality as pure Barred Rock chicks; and (c) that the mortality of all chicks whether from hybrid or pure Cornish eggs was greater than that of all chicks of corresponding matings from Barred Rock eggs. The uncorrected figures of Tables 7 and 8 show the same general trend, though with some differences in detail as is to be expected.

WINTER EGG PRODUCTION IN THE HYBRID AND PURE BRED PULLETS.

The egg production of these hybrid birds in comparison with the pure bred stock is a matter of a great deal of interest. The two breeds crossed differ very markedly in their innate productive capacities. One has good egg production and the other poor egg production as definite and fixed breed characters. In the hybrids is afforded an opportunity to test the question of whether egg production is inherited as a definitely segregable character. To settle this question is a very important matter in connection with the whole problem of breeding for egg production.

In order to get results which shall be in any way reliable in a study of this kind certain conditions have been found in the long experience at this Station in the study of egg production to be of fundamental significance. The most important of these are:

(1) A relatively large number of birds must be trap nested to secure reliable results. Comparisons of egg production based on returns from 5 to 10 birds can only lead to indefinite and uncertain results. Egg production is a character which shows wide fluctuating variability. This condition demands reasonably large numbers of birds, in order to determine the variation constants.

(2) The material must be biologically homogeneous. Lumping together the egg production of several small flocks may give entirely fallacious results.

(3) Environmental conditions must be the same for all birds and average age must be the same.

(4) To get reliable results regarding the inheritance of productivity, experience here has shown most clearly that the environmental conditions (housing, feed, management, etc.) must be *favorable* to good egg production. In other words, something more than simple uniformity of environment is demanded to get reliable results. Only under favorable conditions can the birds bring to full expression their innate laying capacities, whatever they may be. Under unfavorable conditions the interpretation of results must always be uncertain, because it is impossible to say how far an observed result is due to innate and how far to environmental factors. In this same connection it

is of the highest importance to have as a control a flock of birds whose production over a long period of time and under different circumstances is known. The 11 years continuous trap nest records which we have here for the Barred Rock birds is a very important help in work like the present.

(5) The egg production of the winter period (November 1 to March 1) of the laying year, furnishes practically the only data of any use in discussing the problem of the inheritance of production. This period represents a natural unit in the reproductive cycle in the bird's life. Practically nothing is to be gained by studying the production of other periods of the laying year, so far at least as problems of inheritance and breeding of egg productivity are concerned.* The only exception to this statement is with regard to the fall (September 1 to November 1) production of the pullet year. This is, in the laying cycle, a kind of "pre-winter" period. Its production is an artificial result of breeding and domestication in the same way that the winter production is.

The raw data for the winter egg production of the different hybrids and pure bred birds are given in Table 10. This table shows the frequency distributions of egg production.

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*Cf. for discussion of this matter, Pearl, R., and Surface, F. M. A Biometrical Study of Egg Production in the Domestic Fowl. II. The Seasonal Distribution of Egg Production. U. S. Dept. Agr. Bur of Anim. Indus. Bulletin 110, Part II. In press.

Table 10.

Frequency Distribution of Winter (Nov. 1-Mar. 1) Egg Production for Pullets Hatched in 1909.

Eggs Laid in the Winter Period.	Number of Birds Laying the Specified Number of Eggs.				
	Mating: Barred Rock ♂ × Cornish ♀.	Mating: Cornish ♂ × Barred Rock ♀.	Mating: Barred Rock ♂ × Barred Rock ♀.	Mating: Cornish ♂ × Cornish ♀. 1909 hatched.	Mating: Cornish ♂ × Cornish ♀. 1908 hatched.
0–2.9	3	12	22	1	5
3–5.9	4	5	6	5	4
6–8.9	2	6	14	4	1
9–11.9	2	8	7	1	1
12–14.9	2	8	7	2	2
15–17.9	2	7	9	–	1
18–20.9	4	–	13	–	1
21–23.9	3	4	21	–	2
24–26.9	–	4	11	–	1
27–29.9	1	6	22	–	1
30–32.9	2	–	22	–	–
33–35.9	3	6	17	–	1
36–38.9	2	–	17	1	1
39–41.9	4	–	14	–	–
42–44.9	1	3	16	–	–
45–47.9	1	4	12	–	–
48–50.9	1	1	17	–	–
51–53.9	1	–	16	–	–
54–56.9	4	–	5	–	–
57–59.9	3	1	3	–	–
60–62.9	–	1	7	–	–
63–65.9	–	1	5	–	–
66–68.9	1	–	2	–	–
69–71.9	–	–	1	–	–
72–74.9	–	–	1	–	–
75–77.9	–	–	–	–	–
78–80.9	–	–	–	–	–
81–83.9	–	–	1	–	–
Totals	44	78	285	19	25

The constants of variation calculated from these data are given in Table 11.

TABLE 11.

Constants of Variation in Egg Production in Hybrid and Pure Bred Pullets.

MATING.	Mean.	Standard deviation.	Coefficient of variation.
Barred Rock ♂ x Cornish ♀	30.55 ± 1.90	18.72 ± 1.35	61.29 ± 5.83
Cornish ♂ x Barred Rock ♀	19.07 ± 1.23	15.83 ± 0.87	83.05 ± 7.01
Barred Rock ♂ x Barred Rock ♀	32.09 ± 0.70	17.74 ± 0.49	55.28 ± 1.93
Cornish ♂ x Cornish ♀ 1909	9.08 ± 1.33	8.62 ± 0.94	94.91 ± 7.38
Cornish ♂ x Cornish ♀ 1908	15.66 ± 1.59	11.77 ± 1.12	75.18 ± 10.47

From these tables the following points are to be noted:

1. There is a very marked difference between the pullets of the two pure breeds in winter egg production in the present year. This difference is greater in 1909-10 than in 1908-09 (Cf. table 2, page 85). The chief reason is that in 1908 there were a few exceptionally high winter layers, for that breed, among the Cornish. The 1909-10 winter production average for the Cornish probably represents nearer the true breed average than the 1908-09. Furthermore the Barred Rocks at the Station were in 1907, when the present writers began breeding them, in very poor condition as regards egg production, owing to a variety of circumstances not necessary to discuss here. In 1908-09, while there was an improvement of about 7 eggs in the average winter production over 1907, they were still considerably below the normal average winter production of the strain. This normal average winter (November 1-March 1) production, determined from 8 consecutive years of trapnesting, is for the Station Barred Rock stock 36 eggs. In 1909-10 the winter production of the Barred Rocks is approaching this average reasonably closely.

2. Since all birds were kept under the same environmental conditions as to housing, feed, management, etc., and all these conditions were favorable to good egg production, the differences in the winter production in 1909-10 between pure Barred Rocks and pure Cornish are to be considered as innate, breed

differences. These differences consist of (a) a markedly lower mean winter production in the Cornish than in the Barred Rocks and (b) a markedly greater relative variability as measured by the coefficient of variation in winter egg production in the Cornish.

3. The hybrid pullets are seen to fall into two distinct classes in respect to egg production. The barred hybrid pullets coming from the mating Barred Rock ♂ x Cornish ♀ are good winter layers, having about the same mean production as the pure Barred Rocks. The black hybrids, on the other hand, which come from the mating Cornish ♂ x Barred Rock ♀ are relatively poor layers, with a mean winter production more than 11 eggs lower than that of the barred hybrids. In other words, the hybrid pullets whose *mothers* were *good* layers are themselves *poor* layers, while those whose *mothers* were *poor* layers are themselves *good* layers. Could any more striking evidence be adduced to show that the egg record of the mother, in and of itself alone, is a poor indication of what her daughter is likely to lay? Furthermore, the barred hybrids show about the same degree of relative variability in egg production as the pure Barred Rocks, whereas the black hybrids show a much higher relative variability, comparable with that of the Cornish.

These results stated under paragraph 3 are very clear cut and definite, as a study of tables 10 and 11 will demonstrate. They are of much interest, both theoretical and practical. They show that winter egg producing ability is inherited in these hybrids in a manner essentially like that in which the barred plumage pattern is inherited, as described above (pp. 87-89). The behavior of egg productivity in these hybrids is precisely of the kind we should expect to get if it were a "unit character" (i. e., a definitely segregable character) in the Mendelian sense. The facts in hand suggest, though of course they do not prove, that egg productivity is inherited in a sex limited manner, as is barring and shank color (cf. pp. 87 and 107).

The results respecting egg production in these hybrids suggest the Mendelian interpretation given below. Before detailing this particular interpretation it is desired to set forth our position regarding such interpretations in general. It is our opinion, subject of course to modification in the light of compelling facts if such appear, that the purely morphological conception of inheritance which is implied in much of Weisman-

nian and Mendelian theory rests on a very, very slight foundation of objective evidence in the first place, and in the second place has an exceedingly pernicious tendency to obscure or belittle the importance of the fact that inheritance is primarily and fundamentally a physiological *process*. In regard to this matter we are in entire accord with the *general viewpoint* respecting development and inheritance recently so distinctly and forcibly set forth by Lillie* and Riddle.**

The hypothesis here developed is made for strictly utilitarian purposes, and *without any theoretical implication whatever as to the mechanism by which the results symbolized are physiologically brought about.* Indeed these "gametic" formulæ are looked upon by the writers as simply formulæ of symbolic logic. They lead to certain expectations for each generation. Are these expectations fulfilled? If so, the formulæ have served the highly useful and scientific purpose of having predicted the future course of natural events, and may be used in the future to do the same thing again. If they are successful in these predictions there must exist a biological reason why this is so. To determine this reason is a problem for experimental investigation.

Let us consider the three characters (a) barred color pattern, (b) sex and (c) winter laying capacity, denoting the condition of the organism with reference to these characters by the following scheme.

B = barred color pattern present.	b = barred pattern absent, i. e., a non-barred bird.
F = female sex.	f = male sex.
L = Good winter egg production.	l = very poor winter egg production.

Then assume that the breeds crossed in these experiments are constituted as follows with reference to these three characters.

$BfL\,.\,BfL$ = Barred Rock ♂—a barred bird carrying good laying qualities, homozygous with reference to all three characters.

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*Lillie, F. R. The Theory of Individual Development. Pop. Sci. Monthly. Sept. 1909, pp. 239-252.

**Riddle, O. Our Knowledge of Malanin Color Formation and its Bearing on the Mendelian Description of Heredity. Biol. Bulletin, Vol. XVI, pp. 316-351, 1909.

BfL . bFl = Barred Rock ♀—a barred bird carrying good laying qualities, but heterozygous with reference to all three characters, and with good laying associated gametically (or reproductively if one prefers) with the barred pattern.

bfl . bfl = Cornish ♂—a non-barred bird, carrying poor laying qualities, and homozygous in regard to all characters

bFl . bfl = Cornish ♀—a non-barred bird, carrying poor laying qualities, and homozygous in regard to barring and egg production, heterozygous in respect to sex.

We have then for the first cross of a Barred Rock ♂ with Cornish Indian ♀ the following expectation:

BfL . BfL x *bFl . bfl* = *BfL . bfl* = barred male birds heterozygous in respect to all characters except sex.

\+ *BfL . bFl* = barred females which are good layers. This is, as a matter of fact, what we get experimentally.

For the reciprocal cross we have:

bfl. bfl x *BfL . bFl* = *bfl . BfL* = male birds precisely like those from the other cross. This is what is obtained experimentally, at least so far as external characters are concerned.

\+ *bfl . bFl* = non-barred females which are poor layers. This is what is obtained experimentally.

So far as the F_1 generation is concerned the above symbolic development and the experimental facts are in entire accord. The interesting and important point now is: will the expectations deduced from the continued development of the symbolic theory for the F_2 generation be experimentally realized? The answer to this question we hope to be able to report a year from this time.

Inheritance of Shank Color.

The shank color of these hybrids furnishes another instance of sex-limited inheritance, such as has already been described for plumage color (cf. pp. 87-89 *supra*). The evidence for a sex-determined segregation of characters in the F_1 generation is just as definite and convincing in the case of shank color as it has been in plumage color. It has already been suggested by Bateson (*loc. cit.*) that shank color in fowls in general shows a tendency towards sex limitation in its inheritance. Thus he says (*loc. cit.* p. 186): "From many signs we know that there exists some complex relation between the colour of the shanks in fowls generally, and sexual differentiation. Some years ago we described a case of this kind in which the Indian Game ♀ x White Leghorn ♂ always gave F_1 yellow-shanked like both the parent breeds. But White Leghorn ♀ x Indian Game ♂ gave cocks yellow-shanked like the parents, while the hens came with a good deal of pigment in the shanks ranging to nearly a full black.

Another case illustrating this relationship between sex and shank-colour is to be seen in the newly made breed called Black Leghorn. According to the fanciers' ideal both sexes should have full yellow shanks. There is no difficulty in getting this quality in the cocks, but hitherto clear yellow-shanked hens have been very rare, and the same difficulty is encountered in breeding Black Wyandottes."

As is indicated in Table 2 (page 85) both Cornish Indian Game and Barred Plymouth Rock are yellow-shanked breeds. The facts as to the distribution of shank color in the F_1 hybrids are shown in the following table.

Table 12.

Showing the Shank Color of F_1 Hybrids.

Mating.	Shanks of males.	Shanks of females.
Barred Rock ♂ x Cornish ♀	Yellow	Yellow.
Cornish ♂ Barred Rock ♀	Yellow	Black.

The data are seen to parallel exactly those for the inheritance of barring. In the mating in one direction all the offspring are yellow-shanked, whereas in the reciprocal cross the males

come yellow-shanked and the females black-shanked. The females which have the black shanks are the birds which are solid black in plumage color (cf. p. 88).

There is, as would be expected, some variation in the intensity of the black pigmentatioin of the shanks in these hybrids. The color ranges from a very dark bottle green in some cases where the normal yellow is mixed with a relatively small amount of black pigment to an intense coal black in other specimens. In no single specimen would there be any question about classifying the bird as black-shanked. The shanks are *evenly pigmented* with the black pigment, and it is sufficient in amount to give them in superficial examination always a black coloration. *Spots* of black pigment occur more or less frequently on the shanks of the normally yellow-shanked breeds like Barred Rock and Cornish Indian Game. The black coloration of the shanks of these hybrids, however, is of a totally different order. As has been said the pigmentation in the hybrid is evenly distributed over the whole shank.

The coloration of the beak is apparently correlated with the coloration of the shanks. A table exactly like that given above for the inheritance of shank color in the F_1 generation could also be made out for the inheritance of beak color. It appears to be the case that these two portions of the body are correlated quite perfectly with respect to their coloration.

THE DOWN COLOR OF THE HYBRID CHICKS.

As indicated in Table 2 (page 85) the first chick down is normally quite differently colored in the two breeds which were used in these hybridization experiments. The normal down color of the Plymouth Rock chick when just hatched is a dark gray to black with creamery white markings, the belly always being white. The Cornish Indian Game chicks have a beautiful cream colored down with a distinct mahogany or brown pattern on the back. The main feature of this pattern consists of two longitudinal stripes. In the first hybrid generation resulting from crossing these two breeds the down color of the great majority of chicks is uniformly black. The color is a more intense black than that seen in the Plymouth Rock chicks. There is ordinarily no white down whatever on these hybrid chicks. There may, however, be an occasional indi-

vidual varying from the pure and uniform black slightly. One hybrid chick showed to some extent the Game down pattern. A little of the down, particularly in the head region, is in some individual hybrids a very dark red. So far as our observations extend the down color of the chicks is the same regardless of the direction of the cross. The just hatched chicks are not distinguishable in the cross and its reciprocal. The distinction in plumage color between the pullets of the two crosses does not appear until after the birds are feathered out.

If one were anxious to put these results into strictly Mendelian terminology, it might perhaps be said that the Barred Rock chick down condition is dominant over the condition of the down in the Cornish Indian Game. This, however, does not give a fair representation of the actual facts. These facts are, as has been indicated above, that the hybrid chicks are different in appearance when just hatched from either pure Plymouth Rock or pure Cornish Indian chicks. They do not show the down pattern of either breed and furthermore their degree of pigmentation is more intense than that of either breed. In a mixed lot of chickens consisting of pure Barred Rocks and hybrids there is never any difficulty on the part of an experienced person in picking out at once the hybrid chicks frim the Barred Rocks. In other words, here just as in so many other cases, the heterozygotes are recognizable as such by their somatic characteristics.,

THE INHERITANCE OF COMB FORM.

In the hybrids here discussed we have the results of crossing two distinct comb types, as already indicated in Table 2. The Barred Plymouth Rocks have a typical single comb and the Cornish Indian Games have a typical pea comb. With the rediscovery of Mendel's law of inheritance in 1900 one of the first characters to receive investigation was the comb form of domestic fowls. The cross between single and pea comb has been studied by several investigators in the hybrids between a number of different breeds of poultry. In his latest work on the subject, Bateson (*loc. cit.* p. 62) has the following to say regarding the inheritance in this cross of single by pea: "The F_1 from pea by single is pea, that character manifesting a definite dominance. The heterozygous pea combs are generally

higher than the pure pea and may usually, though not always, be distinguished from them. Sometimes the heterozygous pea comb is so large and has the ridges so ill-defined that it approaches the single type, but combs which cannot at once be referred to one class or the other are extremely rare. The distinction is especially sharp in the case of newly hatched chicks, becoming somewhat less marked with later development. F_2 from this cross is of the usual form, three pea: one single."

While, in a general way, the present investigation may be said to confirm the above statement, yet such a statement does not appear to us to give an entirely adequate view of the facts.

In the first place, so far at least as the experimental work at this Station is concerned, involving as it has excellent breeding stock on both sides, the *definiteness* of the dominance of pea over single comb in the first generation hybrids does not impress one. On the contrary there can be no doubt that if a competent poultryman, thoroughly acquainted with the fancy points of poultry, were to go through a large flock of these hybrids as they run on the range he would say that the cross of pea by single, at least as represented with Cornish Indian Games and Barred Plymouth Rocks, results in giving every intermediate condition of comb between perfect pea and perfect single. The number of pea combs obtained in these hybrids which were perfect from the fanciers' standpoint was exceedingly small. Unfortunately it is not possible to measure or to define very precisely the characteristics of these intermediate combs. In taking notes on the birds on the range the only record regarding combs which it was practically feasible to take was that they were either single, intermediate or pea. The attempt was made in every case to indicate in the record whether an intermediate comb was nearer to the single or to the pea type.

The essential results regarding comb inheritance as they appear from the present work may best be set forth as follows:

1. The number of perfect or approximately perfect pea combs, considered from the show-room or fancier's standpoint, which are obtained in these hybrids differs according to the direction of the cross. In the mating Cornish ♂ × Barred Plymouth Rock ♀ a much larger number of relatively good pea combs was obtained than in the reciprocal cross. This was

true for both of the Cornish Indian males which were used in these breeding experiments. It was also true regardless of the females. That is to say, some good pea combs, from the show-room standpoint, were obtained from practically all of the Barred Rock females.

2. The quality from the fancier's standpoint, of the pea comb obtained in the hybrids, depends in some degree on the character of the individual birds used. While, as has already been said, nearly every family of the cross in one direction will yield some individuals with relatively good pea combs, yet it is also a fact that the proportion of relatively good pea combs is very much higher in some families than in others. In certain of the matings all of the intermediate combs are very close to the perfect pea type, whereas in other individual families all of the intermediate combs are much closer to the single comb type. This factor of the individuality of the specimens bred in the determination of the precise condition of bodily characters displayed by the hybrids has been very little taken into account in Mendelian work so far done with poultry. That it is really a very important factor no one who has had experience in the practical breeding of fancy poultry has any doubt whatever.

3. The range of variation from absolutely perfect single combs, on the one hand, to perfect pea combs, on the other hand, is filled without break or gap by small intermediate gradations in comb condition in these hybrids. The occurrence of perfect single combs in the F_1 generation from a cross of pea by single came as a surprise. There can be no doubt, however, of the objective fact. Such combs occur much more frequently in the mating Barred Plymouth Rock ♂ x Cornish Indian Game ♀ than in the reciprocal cross.

The thought is, of course, at once suggested that the reason for the occurrence of these single combs was that we were dealing with a heterozygous individual bearing a pea comb in the original supposedly pure stock. As a matter of fact only one of the hybrid families from which single-combed birds were obtained shows that it is probably of this character. When homozygous single comb is crossed with heterozygous pea comb the expectation is that half of the progeny will bear pea combs and half will bear single combs. In the one family where we

were apparently dealing with a heterozygote individual in regard to comb the figures were as follows:—Mating 426 produced 11 adult offspring distributed as to comb condition as follows: Males, 2 perfect single, 2 intermediate, 1 perfect pea; females, 3 perfect single, 2 intermediate and 1 pea. Putting the intermediate and pea together as showing he pea characteristic in some degree, we have for the total 5 perfect singles and 5 peas or intermediate peas produced in this family. This is in exact accord with Mendelian expectation on the supposition that in this family we are dealing with a heterozygous Cornish Indian Game female as the mother. Whether this is the true explanation of the occurrence of single combs in this family is not, of course, absolutely certain.

The character of the single combs obtained in this family is shown in Fig. 79.

Fig. 79. Photograph of head of hybrid ♂ showing perfect single comb.

The explanation of the occurrence of single combs through a heterozygous condition of one parent by no means holds for all matings where such combs were obtained. In the other matings producing single combs besides 426 there would usually be only one or two single-combed birds out of a family of 10 to 20 peas or intermediates.

4. Detailed data regarding the condition of the comb in these hybrids may next be considered. From the three matings, 420, 422, and 587, there was obtained one perfect single-combed offspring in each case. All of the other offspring of these matings had either perfect or intermediate pea combs. From matings 419, 421, 424, 428, 429, 443, 445, 461 and 589, there were recorded one or more combs in each case as "nearly

single" or "thickened single" or "single in front and thickened behind." In all of these cases the remaining chickens in the same families had either perfect or intermediate pea combs, distinctly bearing in each case the pea characteristics. The total number of offspring in each of these cases may be obtained from Tables 4 and 5 (pages 91-92). All combs recorded as "thickened single" or "almost single" bore no trace whatever of definite lateral ridges such as are characteristic of a pea comb. These combs were single in the important respect that they lacked those parts which make a comb pea. They were not perfect single combs, however, from the fancier's standpoint. They were in almost every case too thick to be recorded as perfect single combs.

5. It is not intended to convey the idea in what has been said above regarding comb inheritance in these hybrids that the hybrid individuals bearing intermediate or single combs will not behave in subsequent breeding essentially like those having more perfect pea combs. This is a matter only to be settled by experimental investigation. The points which it is desired to bring out, with as much emphasis as possible, are (a) that there is no definite and perfect dominance of pea over single comb in these F_1 hybrids; but, (b) that, on the contrary, the F_1 birds, which are heterozygotes, show objectively in regard to comb form a perfectly graded series of comb types, ranging from the perfect single to the perfect pea condition. These facts, however, relate only to the somatic condition of the hybrids. All evidence obtained from the experimental study of inheritance during recent years agrees in indicating that the particular somatic condition of a character is an exceedingly unreliable criterion of the probable behavior in breeding of the individual organism with reference to that character. There is every reason to suppose that this is true with reference to comb inheritance.

6. It is evident that the facts set forth in this section lend themselves very readily to interpretation according to the principle of the imperfection of dominance, lately so fully developed by Davenport* to account for the inheritance of a number

*Davenport, C. B. Inheritance of Characteristics in Domestic Fowl. Carnegie Inst. of Washington. Publ. No. 121. pp. iii + 100. 12 plates, 1910.

of characteristics in poultry. We have not as yet, however, been able to convince ourselves that any real gain is made by such interpretation. We prefer rather to await the collection of a larger bulk of facts before attempting any physiological interpretation of them.

INHERITANCE OF SHAPE OF BODY.

As has been pointed out above in the general descriptions of the two breeds crossed in these experiments, there is a wide distinction between them in regard to shape of body and characteristic carriage. The Plymouth Rock is typical of the American class of birds, whereas the Cornish Indian has a typical game shape, with the characteristic uprightness of carriage in the males that is associated with game breeds. In the hybrids we note the following facts in regard to the inheritance of this character, shape of body. The inheritance here is again definitely related to sex.

1. The male hybrids, regardless of the direction of the cross, are all alike in possessing the characteristic shape of the Cornish Indian Game. They show no trace of the shape of body or carriage which is characteristic of the Barred Plymouth Rock males.

2. The female hybrids, on the other hand, are not so distinctly game-like in their characteristics. On the contrary, there appears here to be an intermediate condition between what is normally found in the two pure breeds. The hybrid pullets are distinctly intermediate in respect to shape of body.

3. There appears also to be some difference here in the result according to the direction in which the cross is made. The barred hybrid pullets as a class conform somewhat more closely to the shape of a pure Barred Plymouth Rock female than do the black hybrids. The black hybrid pullets are nearer to the Game standard of body shape.

SUMMARY.

Certain results in the first hybrid generation of reciprocally crossing Barred Plymouth Rocks and Cornish Indian Games are discussed. At the outstart the characteristics of these two breeds are described. The following points regarding the hybrids are noted:—

1. The barred color pattern is found to be inherited in a sex-limited fashion, equivalent to a phenomenon of segregation in the F_1 generation.

2. The percentage fertility of eggs is found to be much higher when the cross is made in one direction (B. P. R. ♂ x C. I. G. ♀) than in the reciprocal.

3. The hatching quality of the fertile eggs is not found to be greatly different in the cross and its reciprocal. In both cases, however, the hybrid matings gave a much higher average percentage of fertile eggs hatched than did the pure matings.

4. Study of the sex ratios indicates that proportionally more males were produced among the hybrid chicks than among those from pure matings. The difference in the sex ratios cannot, however, be regarded as significant in comparison with their probable errors.

5. The mortality records show that the percentage mortality of hybrid chicks from Cornish mothers was about the same as that of pure Cornish chicks. Similarly the percentage mortality of hybrid chicks from Barred Rock mothers was about the same as that of pure Barred Rock chicks. The percentage mortality of all chicks whether hybrid or pure from Cornish mothers was somewhat greater than that of all chicks of corresponding matings from Barred Rock mothers.

6. The hybrid pullets fall into two distinct classes in regard to winter egg production according to the direction of the cross. Hybrid pullets from Game *mothers* are relatively *good* layers. Whereas hybrid pullets from Barred Rock mothers are relatively *poor* layers. A Mendelian discussion of this result is given.

7. Shank and beak color are shown to be inherited in a sex-limited fashion as is the barred color pattern.

8. The down color of the chicks is different in the F_1 hybrids from what it is in either of the pure breeds crossed.

9. Dominance of pea comb over single is found to be far from perfect. The hybrids show a perfectly graded series of comb types ranging from the perfect single to the perfect pea condition.

10. In shape of body the hybrid males are essentially like the pure Cornish Indian Game males. The hybrid females are intermediate in shape of body between the females of the two pure breeds crossed.

Technical Studies on Poultry Already Published.

A considerable portion of the more technical scientific work of the department of biology of the Station, which has in charge the work with poultry, is published in current biological journals, not readily accessible to the agricultural public. It is the purpose of the present section of this bulletin to give briefly the essential points brought out in certain of these technical studies which have been published during the past year.

SELECTION INDEX NUMBERS IN POULTRY BREEDING.*

It is an obvious fact that a breeder practically never wishes to improve *only* one single characteristic of the plant or animal which he is breeding. What is usually desired is to improve several characteristics at the same time. Thus, with dairy cattle, while the main object in breeding is to increase the amount and quality of the milk, other things such as constitutional vigor, breeding capacity and the like cannot be lost sight of in making the selections of breeding stock. Or in corn breeding, to take an illustration from the plant side, while one may be desirous of increasing the protein content of corn, in breeding for it he must always keep in mind the conformation of the ear, size of ear, yield and a whole series of other characteristics.

One of the special objects of the poultry breeding work at the Station is to learn how to fix superior egg production in a strain by breeding. In any poultry breeding, whatever may be the special object of the breeder, a fundamentally desirable thing is reproductive or breeding capacity in the birds. A "200-egg" hen is of very little value *as a breeder* if she is not able to produce when mated with a good male bird a fair percentage of chickens which will live.

It is very generally stated by practical poultrymen that the point on which it is most often decided whether a given commercial venture in the poultry business shall succeed or fail is the expense involved in the hatching and rearing of the chickens. The female that will produce eggs which will yield a

*This section is an abstract of a portion of the following paper by R. Pearl and F. M. Surface: "Selection Index Numbers and their Use in Breeding." American Naturalist, Vol. XLIII, No. 511, pp. 385-400, 1909.

high proportion of chickens from the eggs set, and whose chickens live through to marketable age, is an extremely desirable bird from a practical standpoint.

The fundamental selection index which we have chosen for poultry relates primarily to the breeding capacity of the female. The value of this index for a particular bird can only be determined after her breeding capacity has been tested. This poultry selection index comes into application in deciding which of the pullets that have been tested as breeders in their pullet year shall be kept over to be used as breeders in their second year of life.

The formula which has been provisionally adopted in our work as a fundamental poultry selection index is as follows:

$$I_1 = \frac{5\,(a + b)}{c + d + 1}$$

The following scheme shows the meaning of the letters in the formula:

I_1 = general or fundamental poultry selection index for an individual bird.

a = percentage of this bird's eggs which hatched.

b = percentage of eggs actually laid by this bird to the total number it was possible for her to lay between February 1 and June 1 (*i. e.*, the breeding season) of the year for which the index is calculated.

c = percentage of this bird's eggs which were infertile.

d = percentage of chicks hatched from this bird's eggs which died within three weeks from the date of hatching.

A brief discussion will make clear the reasons why these particular variables are chosen for the index and are arranged in the formula in the manner that they are. A bird's value as a breeder increases as the percentage of her fertile eggs which hatch increases. Therefore *a* should go into the numerator of the index fraction. Similarly a bird's value increases as a breeder in proportion to her egg production in the breeding season. A bird which produces few eggs during the breeding season (whatever she may have done before) *ipso facto* can not produce many chickens. Instead of using the actual egg pro-

duction in the index the relative or percentage production is used, for reasons which have been discussed in a previous publication by the present writers.*

Now in distinction to the factors so far discussed it is clear that a hen's value as a breeder decreases as the number of infertile eggs which she produces in a given time increases. To put this factor into the breeding index is, of course, equivalent to asserting that the hen plays at least an equal part with the cock in determining fertility. This is undoubtedly the case, for which detailed evidence has been presented elsewhere.** Since relatively poor fertility of the eggs is an undesirable characteristic *c* is put in the denominator of the index fraction. This case is the same in regard to *d*. If the chicks produced by a particular bird are weak and die early when given the same treatment as that under which other chicks thrive, it is an indication that that particular bird is not desirable as a breeder.

Summarizing, we believe the poultry selection index described, or some modification of it to suit particular needs, to be a useful aid in practical breeding operations with poultry. It measures in an exact and impartial manner the performance of a bird as a breeder in any given season. On the basis of the knowledge so gained the breeder can select birds which are to be retained for further breeding. It substitutes an exact and impartial measure, in the place of a rough, general impression of the relative effect of several variables.

The purpose of the paper here abstracted was to call the attention of those interested in breeding operations to the usefulness of what we have called "selection index numbers" in such work. The idea of such index numbers is to combine in a single numerical expression the values of a series of variable characters with regard to all of which the breeder wishes to practice selection at the same time. The analytical expression of this idea is discussed in the original paper and its adaptability and usefulness are illustrated by examples drawn from poultry and maize breeding. It is shown that selection index numbers form a valuable adjunct to the score card in stock judging.

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*Cf Me. Agric. Expt. Station, Bulletin No. 105, pp. 46-48.

**Me. Agr. Expt. Station, Bulletin 168.

POULTRY ABNORMALITIES.

During the past year two papers* dealing with abnormalities of poultry have been published. One of these deals with a case of hermaphroditism and the other with an abnormal egg. The purpose of studying such abnormalities as these is to gain light from them in an indirect way on the normal physiology of egg production. An abnormal specimen is, in a sense, the result of an experiment performed by nature. From such specimens facts of great importance for the interpretation of normal processes may often be learned.

The hermaphrodite specimen may be first considered. From a chick hatched in the spring of 1907, at the Maine Agricultural Experiment Station, there developed the bird which forms the subject of this abstract. This bird was a Barred Plymouth Rock and when adult presented externally the general appearance of a normal hen of this variety, so far as the characters body form and plumage color were concerned (cf. Fig. 81). As the photograph in Fig. 81 shows, however, the head and neck resembled these parts in a cockerel. This resemblance was especially remarkable in respect to the size and shape of the comb and wattles. The comb was obviously much larger than the comb of a normal Barred Plymouth Rock hen and looked exactly like the comb of a male bird. This was also true of the wattles.

The dimensions* of the comb of this bird were as follows:

Length	88.4 mm.
Calculated height	25.1 mm.
Area	22.2 cm.

For normal adult Barred Plymouth Rock females the following average values for comb size have been found:**

Mean length	$50.80 \pm .56$ mm.
Mean calculated height	$10.57 \pm .23$ mm.
Mean area	$5.59 \pm .17$ cm.

*These papers are (1) Studies on the Physiology of Reproduction in the Domestic Fowl. III. A Case of Incomplete Hermaphroditism. Biol. Bulletin, Vol. XVII, pp. 271-286, 1909. (By R. Pearl and Maynie R. Curtis). (2) A Triple Yolked Egg. Zool. Anzeiger, 1910. (In press). (By R. Pearl).

*Made in accordance with the methods described by R. and M. D. Pearl in a paper "Data on Variation in the Comb of the Domestic Fowl," *Biometrika*, Vol. VI, pp. 421-423.

**Pearl, R. and M. D., *loc. cit.*, p. 427.

Fig. 80. Outline of the lateral aspects of the comb of the Barred Plymouth Rock hen described in this paper. This outline is actual size.

It is evident from these figures that the comb in this specimen greatly exceeds in size the average for females of the variety.

In regard to behavior this bird resembled a normal hen rather more than a cock. She was never heard to cluck, however, or to make any of the sounds which normal active hens make in the course of the day's work. This bird probably never laid an egg, though we are unfortunately not able to make an absolute statement on this point. The egg records of the Station show an egg to the credit of this bird on November 7, 1907. This was the only egg ever recorded for this bird, and it is undoubtedly an erroneous record. The condition of the sexual organs was not such as to indicate that they had ever been functional.

Cockerels placed in the pen with this bird would try to fight with her as if she were a cockerel, but she would not fight. We have no evidence that a cockerel ever attempted copulation with this bird. These facts are of interest in relation to the question of the basis of sex-recognition and the assortative mating known to occur among fowls. Is a normal pullet with an unusually large comb less likely to have her eggs fertilized than a bird with a smaller comb?

This bird was observed occasionally to take the position of a cockerel about to crow and attempted to crow but never succeeded in very closely approximating the sound of a normal cock bird. The bird was never seen to attempt to tread a hen.

Anatomical study of this bird showed that on the left side of the body were organs normal to a female (ovary or egg cluster, and oviduct or egg tube). On the right side were organs like those normal to a male (testicle and vasdeferens—the tube which conveys the spermatozoa from the testicle to the outside). Microscopic examination showed that neither the male nor the female organs had probably ever been functional.

The appearance of this hermaphrodite is shown in Fig. 81. Anteriorly the bird was male in its external characters; posteriorly it was female. The truth of this statement may be demonstrated in a striking manner by placing the edge of an opaque card along a line connecting the letters *a* and *b* in Fig. 81 and turning the card about this edge as an axis so as to expose alternately the anterior and posterior parts of the bird.

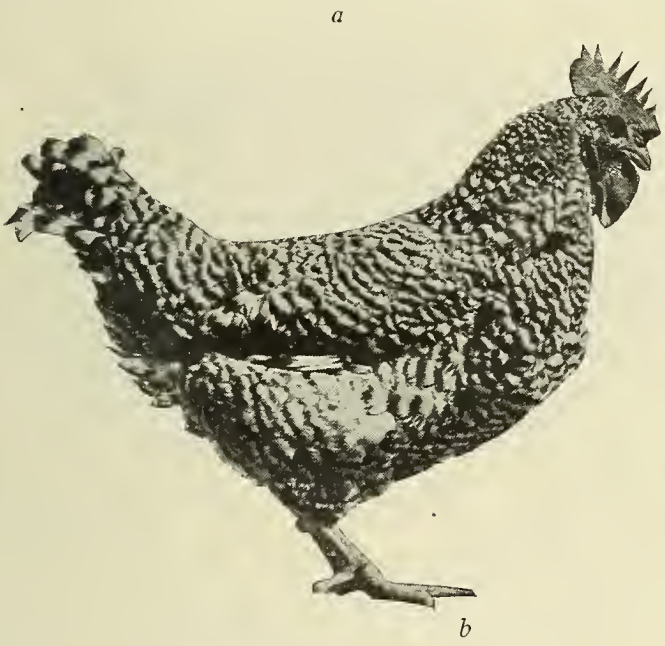

Fig. 81. Hermaphrodite Barred Plymouth Rock.

When the card covers the posterior part of the bird what one can see (*i. e.*, the anterior part) is unmistakably and indubitably male. On the contrary, when the anterior part is covered by the card, what of the bird is then to be seen is equally unmistakably female. The "maleness" and "femaleness" of these two portions of the body extend to the most minute details of structure, perhaps not apparent to anyone not perfectly familiar

through first-hand practical experience with poultry and particularly Barred Plymouth Rocks. Thus the beak—which is not ordinarily reckoned as a secondary sexual character—in this bird is to the fancier unmistakably that of a male.

The triple yolked egg shown in Fig. 82 was laid September 27, 1909, by a Barred Plymouth Rock pullet bearing the leg-band number 318. This pullet was hatched March 29, 1909. Its growth and physiological development were normal. During the spring and summer this chick was kept with others in a large field of grass, where it was under free range conditions. On September 1, 1909, this pullet, along with others, was put into the poultry-house which provides permanent winter quarters. She began laying about three weeks after this removal to the house. Her complete laying record to the date of writing is as follows:

Fig. 82. Photograph (approximately natural size) of the triple yolked egg described in the text.

One egg was laid by bird No. 318 on:—

September 21, 24, 25, 26, 27, 30.
October 2, 3, 4, 5, 8, 12, 13, 16, 17, 19.

So far as is known the first three eggs laid by this bird were entirely normal. That laid on September 26 was "soft-shelled," *i. e.*, bore only the shell membrane as an outside covering, with only a slight deposit of lime in the form of a true shell. This was followed on the 27th by the triple yolked egg. Since that date the eggs from this bird have been normal. The laying of the "soft-shelled" egg and the triple yolked egg on successive

days indicates that the whole reproductive mechanism was not functioning in a normal, orderly and regular manner at that time. The egg record at the time of laying of the triple yolked egg indicates the reason of its formation. From the 24th to the 27th inclusive the bird laid an egg each day. The egg of the 27th has three yolks. On the 28th and 29th no eggs were laid, but one was on the 30th. There should appear to be little doubt that one of the extra yolks in the triple yolked egg should normally have been laid in an egg of the 28th, and the other in an egg of the 29th. Instead of this, however, the three yolks which normally should have been laid on the 27th, 28th and 29th were all discharged from the ovary at so nearly the same time as to pass down the oviduct in one group. The case simply indicates that perfect *regularity* in rate of ovulation had not become firmly established at this time.

Bird No. 318 belongs to a family of relatively high fecundity. Her mother laid 177 eggs between November 16 and July 31 inclusive of her pullet year. This is a record well above the average for the general flock of that year 1908-09. The records show no abnormal eggs as having been produced by either the mother or the grandmother or sisters of bird No. 318 except for an occasional "soft shelled" specimen. There is thus no evidence of an inheritance of the tendency to lay multiple yolked eggs in this family. Experience in this laboratory where detailed records of large numbers of birds are kept shows that any individual is liable to produce at some time in her laying career an abnormal egg. If even mother and daughter should both chance to do this in one or two isolated instances it is no proof of inheritance.

The rarity of the occurrence of triple yolked eggs is indicated by the statement of a French scientist, Valenciennes, to the effect that the marketmen of Paris estimated that such eggs were found not more than 5 or 6 times in a year, at a time when the annual official receipts of eggs amounted to over 141 millions.

The disposition of the three yolks in this egg is clearly shown in Fig. 82. Each yolk was enclosed in a separate yolk membrane. While the three yolks were in contact with each other, they were in no way fastened together. All of the yolks were of normal size, and of approximately the same size. Unfortunately no measurement of the yolks are available. Each yolk

possessed a germ disc. These were normal so far as macroscopic appearance indicated. The germ disc on the yolk nearest the pointed end of the egg shows very clearly in Fig. 82.

The two kinds of albumen (of thick and thin consistency) which are normal were present in this egg. There was no trace of a chalaza in connection with any yolk or at either pole of the egg.

The shell membranes were entirely normal.

It is shown that, in so far as the four different classes of eggs in respect to the number of contained yolks which are known to occur, the relation of the observed size of the entire egg (measured here by weight) to the number of yolks, is very accurately described by a parabola.